RESERVOIR PETROLOGY AND PRODUCTION CHARACTERISTICS
OF THE LYTTON SPRINGS OIL FIELD,
CALDWELL COUNTY, TEXAS

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RESERVOIR PETROLOGY AND PRODUCTION CHARACTERISTICS OF THE LYTTON SPRINGS OIL FIELD, CALDWELL COUNTY, TEXAS

by

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THESIS

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PREFACE

This thesis is a report of the geology and producing characteristics of the Lytton Springs oil field located in Caldwell County, Texas. X-ray diffraction techniques and thin sections were employed to study the mineralogy of the altered igneous rock commonly referred to as serpentine, from which the oil is being produced. Decline curves were used to study the production characteristics of the field and to make predictions as to the effect of gravity drainage on future production.

This work is the result of a suggestion made by Dr. H. H. Power, Department of Petroleum Engineering, The University of Texas, to whom I wish to express gratitude for his guidance and counsel. Appreciation is also expressed to Dr. S. E. Clabaugh for his invaluable assistance in describing the mineralogy of the altered igneous rock. My wife, Louise, is also due acknowledgement for her patience, understanding and encouragement during this work.

Scott Petty, Jr.

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CHAPTER I

INTRODUCTION

The Lytton Springs oil field, located in Caldwell County, Texas, is one of more than seventeen fields producing from an altered igneous rock, commonly referred to as serpentine, that have been discovered in the Coastal Plain of Texas.[1] The producing formation, which lies approximately 1200 feet below ground level, covers a nearly circular area and has structural relief of over 600 feet. The altered rock is the aftermath of an explosive volcano which broke forth during the late Cretaceous.

Production from the field during the first few years was the result of solution gas drive, but due to lack of gas and pressure most of today's production is being attributed to gravity drainage.[2] Accumulated production to January, 1961, was somewhat over nine million barrels of oil, which represents only about 30 percent of the estimated twenty-seven million barrels of oil originally in place. The possibility of the recovery of a few percent of the eighteen million barrels of remaining oil is significant enough to warrant further studies of this field.

Until recently very little mineralogical work had been done on the type of rock from which the oil at Lytton Springs

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[1] References are given at end of thesis.

was being produced. In a fairly recent publication, a very similar rock from Pilot Knob at the outskirts of Austin was examined with x-ray diffraction techniques and found to be composed chiefly of montmorillonite minerals.[3] From the conclusions reached in the above paper, it is obvious that before any additional stimulation techniques are tried at Lytton Springs, the "serpentine" should be analyzed to determine whether or not it contains montmorillonite which hydrates readily when in contact with most waters. Information also of interest for any future work in this field would be the present and future location of the best oil saturation per acre-foot of rock. If gravity drainage has a large role in production at the present time it is quite possible that future tests should be carried out on the flanks of the dome rather than in the center of the mass. This investigation was carried out to arrive at a better idea of the composition of the "serpentine" rock and also to determine what effect, if any, gravity drainage has had on past production and what possible effect it will have on the location of the most advantageous area to commence future secondary recovery operations.

CHAPTER II

LOCATION AND HISTORY

The Lytton Springs oil field is located in a portion of the Gulf Coastal Plain in Caldwell County, Texas. It lies approximately twenty-eight miles south of Austin, two miles southeast of the town of Lytton Springs and eight miles northeast of Lockhart. The main Balcones fault zone is about fifteen miles to the northwest and the Luling-Mexia fault zone is about five miles southeast.[4] The field is situated upon a small oval hill; however the surface relief of that immediate area probably does not exceed one hundred feet. The area is drained by Walnut Creek which empties into the Colorado River.

Mr. John Blanchard with the Gulf Production Company first mapped the surface structure of the Lytton Springs field.[5] The discovery well, drilled by Lefevre and Storey, was completed on March 13, 1925. It was located in the northwest corner of Lease 13 in the Jonathan Burleson Survey. The discovery well is reported to have had an initial flowing potential of seventy-five barrels of oil per day, with no water.[5] To date there have been a total of 461 wells drilled, of which 95 were dry holes and 366 were producers. It is reported that by March, 1926, there were 366 wells drilled, of which 325 were productive.[6] The main rush of drilling came during the first five months after discovery. From early records of the Texas Railroad Commission, the average time to drill and complete the wells was approximately twelve days; however there are records to show that at least one well was drilled to a depth of 1870 feet and completed within a fifty-six hour period.[5]

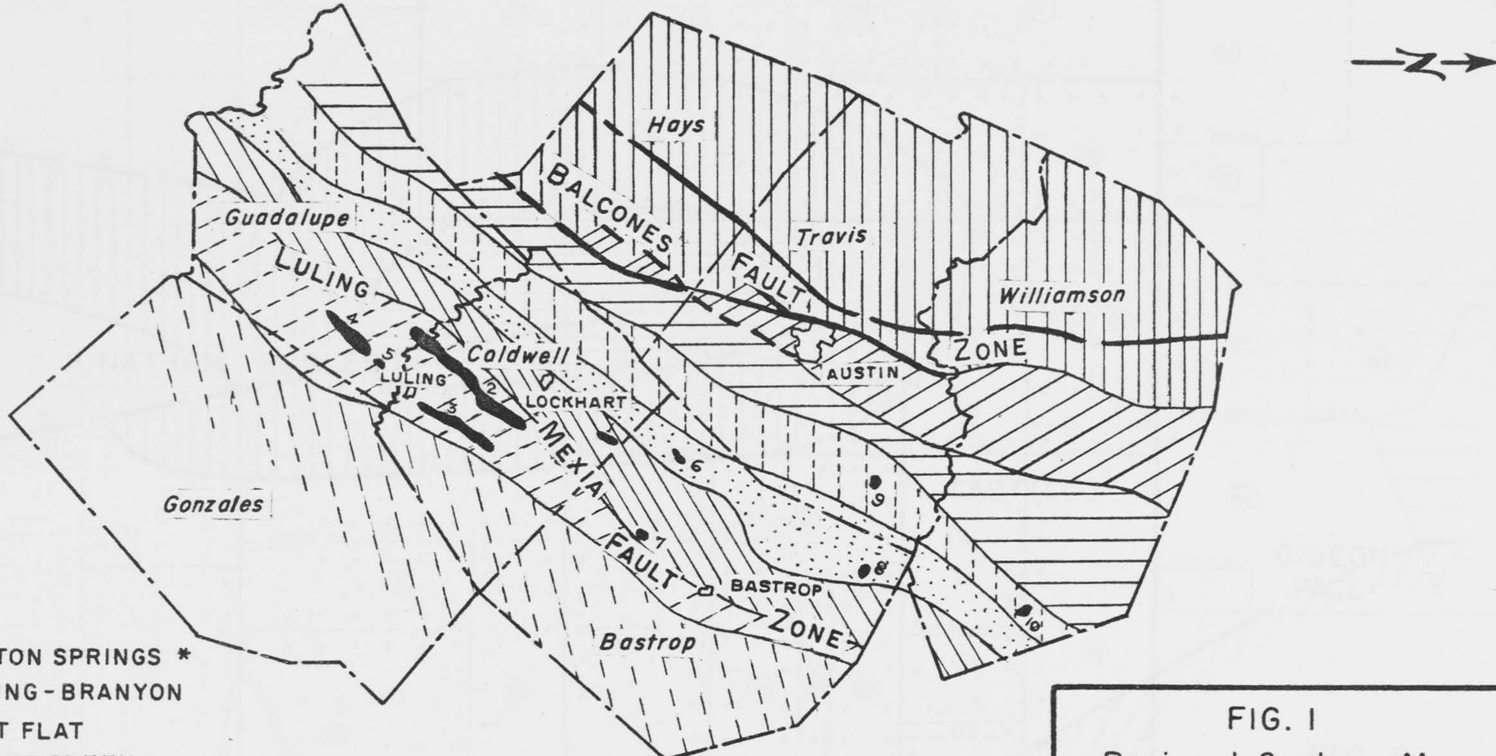
The peak production for the field was reached about four and one-half months after discovery, when the production averaged 15,000 barrels daily. Production at the present time is averaging 116 barrels daily. During the first year the field produced over 2,500,000 barrels of oil, and has a cumulative production record through December 1960 of slightly over 9,000,000 barrels. The oil produced is about 38.5° API and has a paraffin content between 6 and 7 percent.

CHAPTER III

GEOLOGY OF NON-PRODUCTIVE ROCKS

The formations exposed at the surface in the vicinity of the Lytton Springs field are the Wilcox and Midway of the Lower Eocene.[6] The regional geology of the area surrounding the Lytton Springs field is illustrated in Figure 1. The larger oil fields are noted along with the locations of a few fields in the area that are producing or have produced from rocks similar to those yielding oil at Lytton Springs. The dome on which the field is located is easily recognized from outcropping formations. Figure 2 shows the surface geology of the Lytton Springs field and immediate area. In addition to the outcropping formations, formations of the Upper and Lower Cretaceous were encountered in the course of drilling wells in the area. Table 1 shows the typical geologic column of the Coastal Plains area.

The normal dip of the surface strata is between 1 and 2 degrees to the southeast and the strike in general parallels that of the main Balcones fault zone, or North 35° East.[7] The Midway formation has been subdivided into three groups for purposes of illustration to show the doming effect of the producing rock. The subdivisions used are those proposed by Collingwood and Rettger, and are based upon lithology-concretions and percentages of greensand.[6]



1. LYTTON SPRINGS *
2. LULING - BRANYON
3. SALT FLAT
4. DARST CREEK
5. MANFORD *
6. YOST *
7. HILBIG *
8. ELGIN *
9. KIMBRO *
10. THRALL *

* "SERPENTINE" PLUGS

MT. SELMAN	NAVARRO
CARRIZO	TAYLOR
INDIO	AUSTIN
MIDWAY	LOWER CRETACEOUS

FIG. I
Regional Geology Map
Central Texas

0 10 20
Scale: miles

S.P. Jr. July 1961

After: [6] Collingwood & Rettger

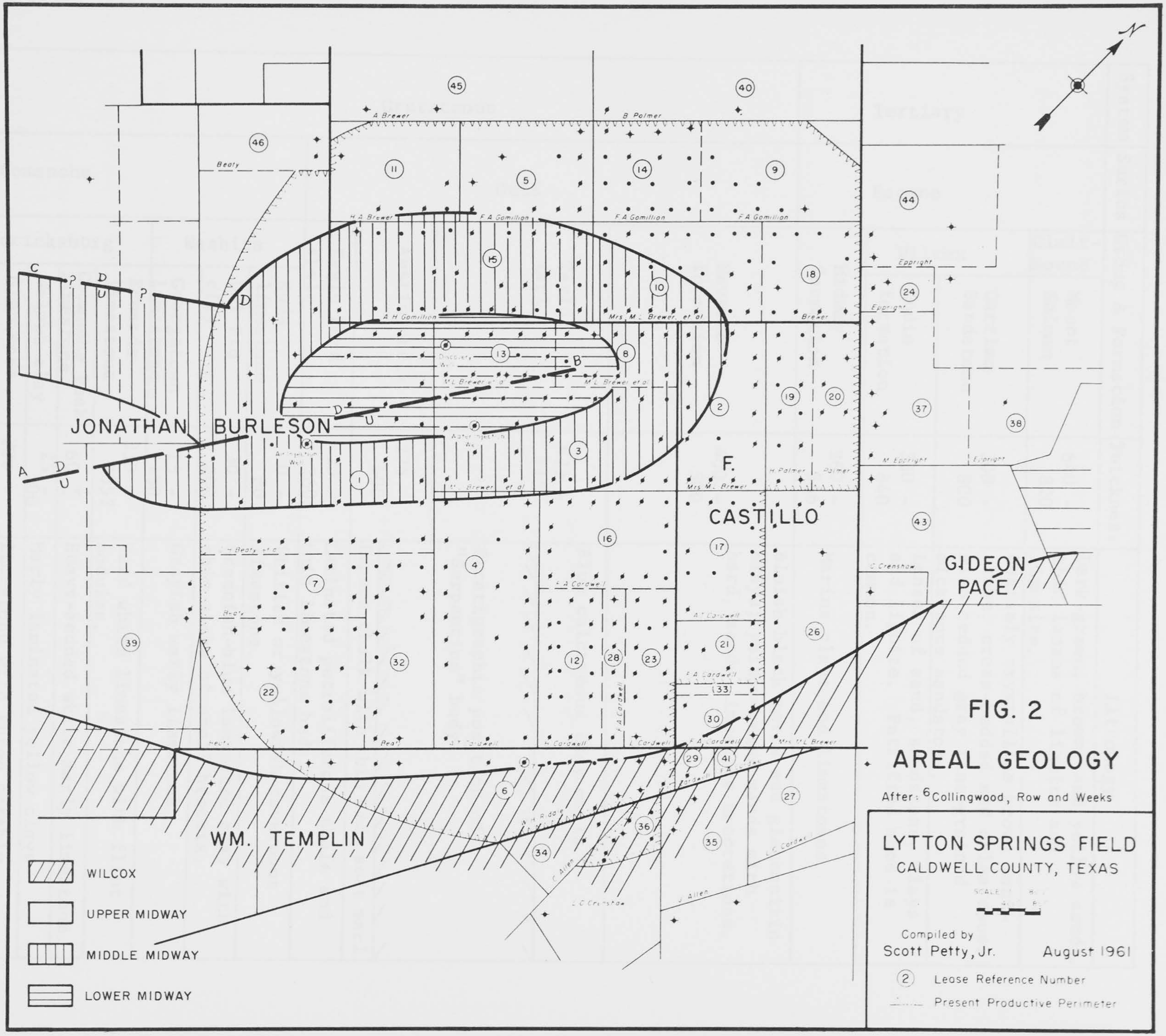


FIG. 2

AREAL GEOLOGY

After: [6]Collingwood, Row and Weeks

TABLE 1

GEOLOGIC FORMATIONS IN THE COASTAL PLAIN OF TEXAS

System	Series	Group	Formation	Thickness	Lithology
Tertiary	Eocene	Clair-borne	Mount Selman	640 - 820	Dark-green, brown, and yellow sands, thin lenses of lignite and limonite.
		Wilcox	Carrizo Sandstone	300 - 800	Coarsely crystalline brown sandstone, cross-bedded and calcareous. Also bedded gray fine-grained micaceous sandstone.
			Indio formation	350 - 840	Lenses of sand, sandstone, clays and lignite. Petrified wood is common.
			Midway formation	260 - 566	Marine clays and limestones
Cretaceous	Gulf		Navarro formation	400 - 500	Bluish-black marls and glauconitic clays; yellow-brown sands with hard, sandy limestone concretions.
			Taylor marl	475 - 1150	Blue calcareous clay marls Stratigraphic position of "Serpentine" body
			Austin chalk	275 - 600	Impure chalk with thin beds soft marl
			Eagle Ford shale	25 - 260	Laminated petroliferous shale and thin limestone beds.
	Comanche	Washita	Buda limestone	0 - 80	Whitish or yellowish cavernous limestone.
			Del Rio clay	30 - 200	Greenish-blue laminated clay with thin slabs of shell breccia.
			Georgetown limestone	15 - 150	Grayish marly limestone
		Fredricksburg	Edwards limestone	250 - 835?	Hard white limestone with flint nodules.
			Comanche Peak limestone	60 ±	Heavy-bedded white marly limestone.
			Walnut clay	25 - 200	Marly laminated yellow clays
			Glen Rose limestone	300 - 600	Limestone with three notably sandy horizons
			Travis Peak sand	250 - 300	Sand and limestone with bands of limestone.

After: [8]Deussen

Faulting and folding have caused repetition of many of the beds in surface outcrops. Two faults and possibly more have been located on the surface.[6] Both faults are trending in a northeasterly direction and are upthrown to the southeast. The most important fault (A-B) extends southwest from about the center of the field and has an average displacement of around 100 feet. The other fault (C-D) is not definitely proved to be present but was used by Collingwood and Rettger to explain the surface exposures encountered in that location.[6] Fault C-D is also striking in a northeasterly direction and upthrown to the southeast. The preceeding faults are probably some of the northwestern faults of the Luling-Mexia fault zone which trends approximately North 35°East and is upthrown to the southeast. The main faults of the Luling-Mexia zone are located about five miles to the southeast.

As indicated by the outcropping formations in Figure 2, the dome structure of the field is outlined by folding in the Midway and Wilcox formations. The Lower Midway which is exposed on top of the field is surrounded by Middle Midway. The contacts between the Middle and Upper Midway, and Upper Midway and Wilcox formations are bowed to indicate the existing dome structure.

Subsurface formations encountered in drilling at Lytton Springs were those of the Gulf and Comanche Series of the

Cretaceous as noted in Table 1. Where the altered igneous rock is present, no markers have been distinguished between the top of the Taylor marl and the bottom of the Austin chalk. The Austin chalk has been shown by several writers to exhibit a doming effect and it has been proposed that the formations underlying the Austin chalk might also be domed to a certain extent.[6]

Faulting is also indicated in the subsurface formations. Evidence is given in the literature to substantiate Fault A-B with subsurface data.[6] One well which is thought to have cut Fault A-B went from Austin chalk to Edwards limestone within 80 feet indicating a displacement for the fault of 220 feet. Most of the wells which are believed to have cut this fault have produced much larger quantities of water than the other wells in the field. As a matter of fact, the rest of the field is generally lacking in water production. The only logical explanation for the present water production is that the water is migrating upward along the fault plane to the "serpentine" from the underlying Eagle Ford or Edwards formations.

CHAPTER IV

GEOLOGY OF THE PRODUCTIVE FORMATION

As stated earlier, the productive formation at Lytton Springs is an altered igneous rock called serpentine, which, up until recently, was thought to have been composed mostly of the minerals antigorite and chlorite. The mass was formed during the late Cretaceous when there came into existence a chain of volcanoes along a belt extending through central Texas. These volcanoes broke forth with explosive violence in the shallow Austin sea and built mounds of rock fragments and lava flows which were later buried by limestone and shale. Figure 17 is a structural map of the top of the "serpentine" while Figure 18 is an isopachous map of the mass. The cone shape and a certain amount of cratering can be seen in Cross Sections A-A' and B-B'. The exact shape of the mass is somewhat doubtful because very few wells actually penetrated all of the "serpentine," and the position or even presence of the volcanic neck is no more than a shot in the dark. However, none of the wells located above the proposed neck have been drilled through the "serpentine" into sedimentary rocks.

The word serpentine in common usage is restricted as a mineral name to the minerals antigorite and crysotile and as a rock name to rocks composed mostly of these minerals. Since the following analyses show that the altered igneous rock

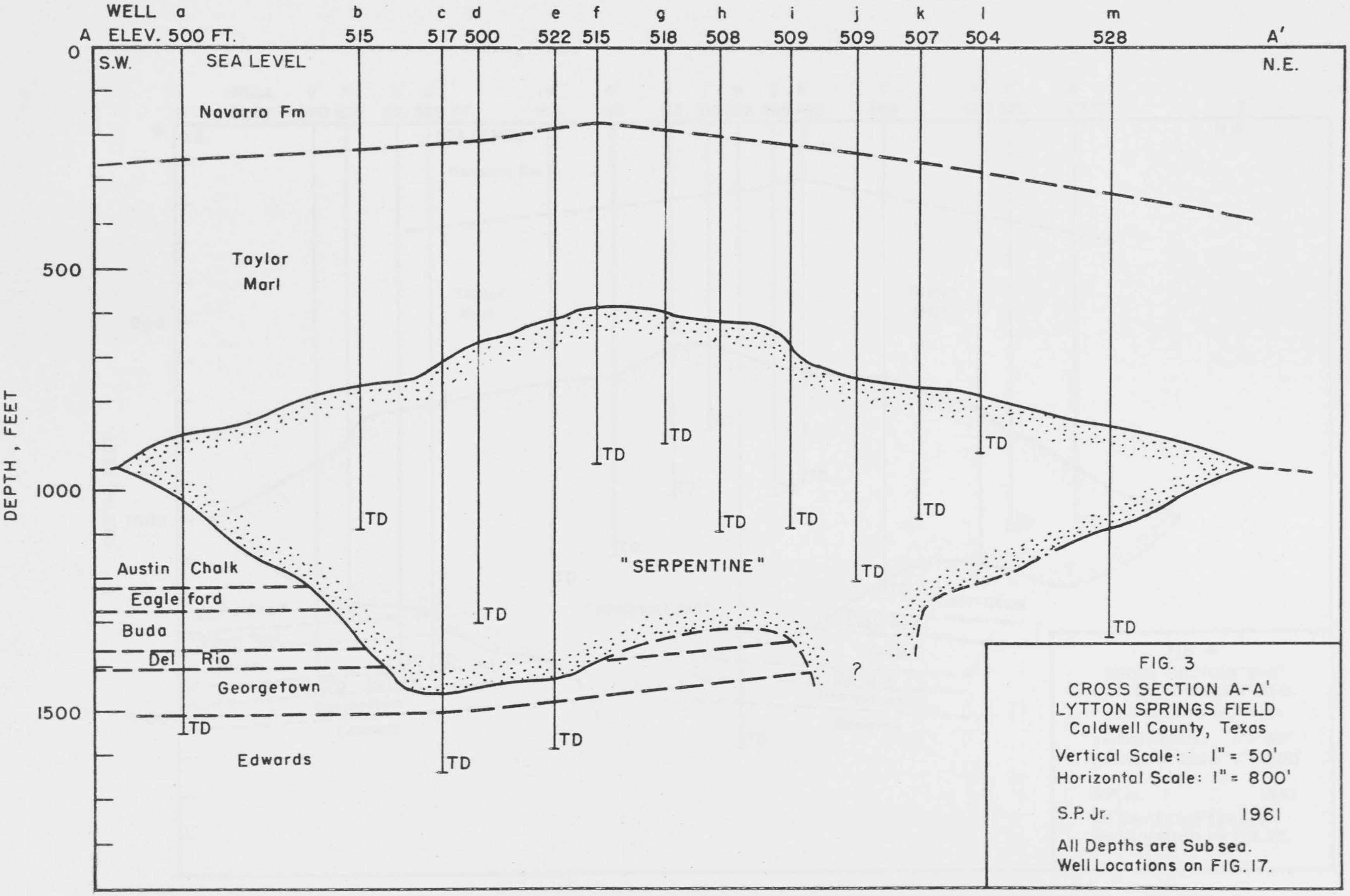


FIG. 3
CROSS SECTION A-A'
LYTTON SPRINGS FIELD
Caldwell County, Texas
Vertical Scale: 1" = 50'
Horizontal Scale: 1" = 800'
S.P. Jr. 1961
All Depths are Subsea.
Well Locations on FIG. 17.

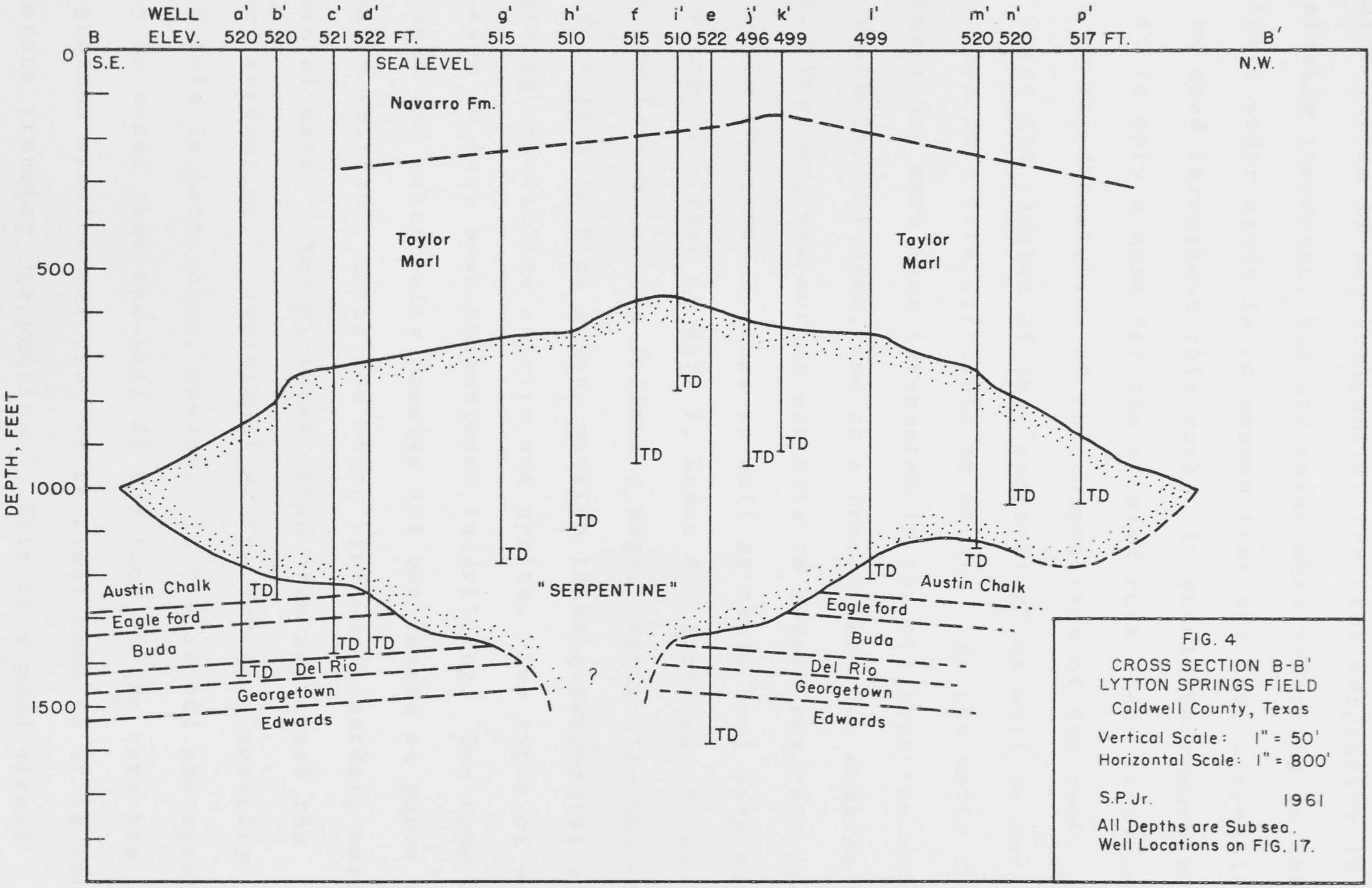


FIG. 4
CROSS SECTION B-B'
LYTTON SPRINGS FIELD
Caldwell County, Texas

Vertical Scale: 1" = 50'
Horizontal Scale: 1" = 800'

S.P. Jr. 1961

All Depths are Sub sea.
Well Locations on FIG. 17.

contains little if any antigonite, the name serpentine is technically incorrect, but its usage when referring to the oil field under study is so common that the name serpentine will be used throughout this work. It should be remembered that it is only a name for the altered rock under study and is in no way descriptive of the composition of the rock.

Cores and samples of the "serpentine" as well as early production data were difficult to obtain. In the early days, the operators were more interested in the oil than the rocks from which the oil came, and as a result very few samples were saved. However, the author was able to obtain several cores from wells at Lytton Springs as well as cable tool samples from every five feet in Well 7, Lease 6. Pictures of the cores may be seen on the following page. Externally the rock is a dark gray to blue green, massive looking fragmental rock, containing crystalline calcite and pyrite. Two types of material seem to have been encountered in drilling. One type was very soft and essentially massive and was logged as gumbo by the early drillers, while the other type was a harder, more fragmental mass.[5] The pictures shown here represent the harder "serpentine." Individual grains and good porosity are visible in both cores; however, in the second photograph it may be noted that one-half of the face of the core has very fine-grained massive texture, while right next to it is found the porous granular "serpentine." This is a good visual

Figure 5

Photographs of "Serpentine" Rock
from Lytton Springs Field

1

2

3

illustration of the over-all heterogeneity of the formation. In order to obtain some idea as to the present composition of the "serpentine," samples were selected for x-ray and thin section analyses. The samples that were used came from Well 7, Lease 6, and their depths are indicated in Table 2. These samples were chosen in such a manner as to give some idea of the variation, if any, in the "serpentine" rock with depth. In addition to these samples, fragments from three nearby "serpentine" plugs (Elgin, Yost and Hilbig) were also subjected to x-ray analysis.

Principles of X-ray Diffraction

In a manner similar to the ultra-violet, visible and infrared radiations, x-rays exhibit a dual nature, behaving sometimes as waves and other times as particles.[9] X-ray diffraction work is concerned only with the wave nature of the x-rays. X-ray tubes used in diffraction work produce x-radiation of known wave lengths.

All crystalline matter is composed of atoms and molecules arranged in definite forms of geometric space packing, and in such a manner that they form definite families of planes in various directions through the crystal.[10] The Bragg relationship is used for determining the lattice spacing from the reflection angles. At each atomic plane a portion of the x-ray beam is reflected and the angle of reflection may thereby be related to the spacing between planes by the following statement of Bragg's law:

$$n \lambda = d \sin \theta$$

where: n = an integral number of wavelengths;

λ = wavelength of the x-rays in angstroms;

d = interplaner spacing in angstroms;

θ = angle of incidence of the x-ray beam with the sample.

In actual practice the angle 2θ with respect to the undeviated incident beam is measured, and, with a knowledge of the wave length of the x-rays being generated, the lattice spacing, d, is easily calculated.

Sample Preparation and Analysis

Since the clay minerals exist for the most part in very fine particles, some type of x-ray powder method must be used. The samples to be studied were prepared by first crushing each sample and passing it through a 325 mesh screen, and then dispersing it in enough water to make about 0.1 normal solution. The samples were then allowed to stand for 48 hours, during which time they were shaken at irregular intervals. This allowed enough time for the montmorillonites, if any, to hydrate. After 48 hours, a small portion of each sample was placed on a glass slide and allowed to air dry, in order to obtain parallel orientation of the platy minerals. When the samples were dry, they were then placed overnight in a dessicator, the bottom of which was partially filled with a saturated solution of calcium nitrate to maintain it at 50 percent relative humidity.

As shown in the literature, montmorillonite possesses the property of adsorbing certain organic molecules between the individual silicate layers, with a consequent shift in the basal spacing.[11] Treatment with organic compounds permits the investigator to distinguish montmorillonite from various other minerals yielding x-ray diffraction patterns very similar to those of montmorillonite. A special method for introducing ethylene glycol between the layers of montmorillonite and causing an expansion of the crystal lattice was used.[3] The technique consists of pouring ethylene glycol into the bottom of a dessicator and placing the slide on which the sample was sedimented above the glycol. The dessicator is then heated to 65°C for one hour. Glycolation by this method was carried out on several samples after a diffraction pattern had been run on the untreated sample. Because this method of glycolation did not change the orientation of the mineral grains, the patterns obtained before and after treatment were easily compared.

After the samples were prepared, x-ray diffraction patterns were obtain from each, and then from the glycolated samples. The patterns for the untreated samples were obtained with a General Electric XRD-5 x-ray diffraction machine, using 180° arc and Copper Kα radiation. The diffraction patterns for the glycolated samples were obtained using a 180° arc North American Phillips Company diffractometer and Copper Kα radiation. Both machines were calibrated similarly and the results were the same regardless of the machine used. A test pattern was run where 2θ varied from 2 degrees to 90 degrees. Due to the absence of characteristic reflections past 35 degrees, the remaining patterns were run only to 40 degrees, which is considered sufficient for most qualitative clay determinations.

Results

The interplaner distances obtained from the diffraction patterns are presented for comparison in Table 3. The diffraction tracings for two samples that were glycolated are included as Figure 6, and the resulting interplaner distances are compared in Table 4.

Since it may be seen that all of the samples showed a fairly constant composition, only Sample 2 (Figure 6) will be considered in detail. Its most characteristic feature is a strong peak in the vicinity of 14.7 angstroms, all other peaks being considerably weaker. The intense peak in the region of 15 angstroms and the relative heights and positions of the other peaks indicate that the sample is mostly a montmorillonitic material. The lower tracing shows that glycolation expanded the basal spacing from about 14.7 to 16.6 angstroms, and that the peak is more intense and better resolved. This

TABLE 2

SAMPLE NUMBERS AND DEPTHS FROM WELL 7, LEASE 6, LYTTON SPRINGS FIELD

Sample Number	Depth, feet below surface
1	1610-11
2	1628-29
3	1661-63
4	1693-95
5	1713-17
6	1732-34
7	1784-86
8	1796-98
9	1837-39
10	1887-89
11	1915-17
12	1929-33

Sample Numbers for Samples from Three Nearby "Serpentine" Plugs

13	Elgin
14	Hilbig
15	Yost

TABLE 3

RESULTS OF X-RAY DIFFRACTION ANALYSIS

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Interplaner Distance in Angstroms	14.48	14.72	14.48	14.72	14.48	14.72	14.72	14.98	14.72	14.15	14.48	14.48	12.8	14.72	14.72
	9.93							10.04	10.04	10.04	10.04	9.93			10.91
								7.62							
	7.21	7.19	7.19	7.25	7.25	7.25	7.21	7.19	7.19	7.19	7.19	7.19	7.25	7.34	7.25
	4.82	4.77	4.82	4.79	4.79	4.82	4.79	4.79	4.79	4.82			4.82		4.87
	4.60													4.62	4.64
	3.59	3.59	3.59	3.60	3.58	3.58	3.59	3.57				3.85		3.85	
		3.09			3.09	3.08		3.07	3.59	3.59	3.61	3.57	3.60	3.52	3.50
		3.02		3.02	3.03					3.31	3.34	3.31			
		2.87		2.87		2.86	2.88		3.03	3.03	3.03	3.02	3.07	3.05	3.03
												2.88		2.84	

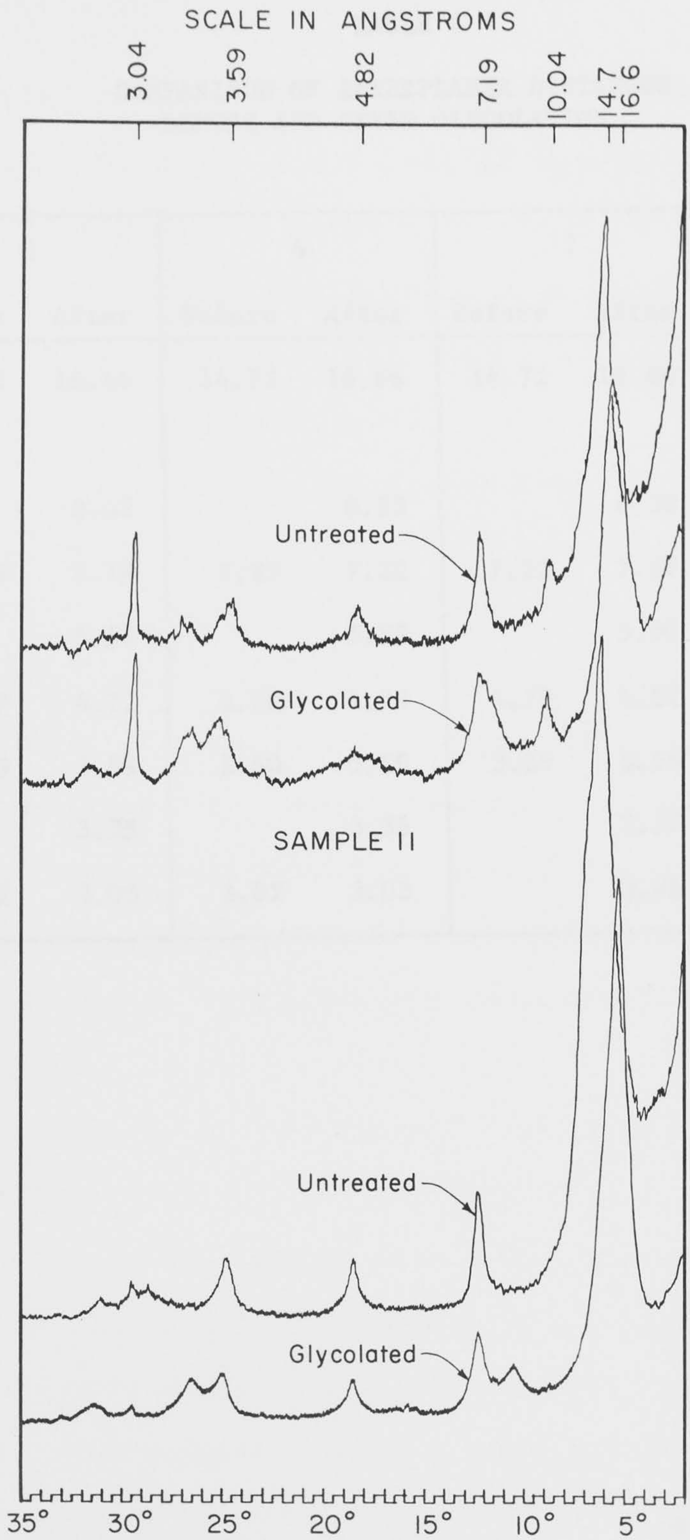


FIG. 6. DEFRACTOMETER TRACING OF UNTREATED AND GLYCOLATED SAMPLES OF "SERPENTINE", LYTTON SPRINGS FIELD

TABLE 4

COMPARISON OF INTERPLANER DISTANCES
BEFORE AND AFTER GLYCOLATION

Sample	2		4		7		11	
	Before	After	Before	After	Before	After	Before	After
Interplaner Distances in Angstroms	14.72	16.66	14.72	16.66	14.72	16.84	14.48	15.49
							9.93	9.93
		8.42		8.85		8.38		7.59
	7.19	7.19	7.25	7.22	7.22	7.22	7.19	7.19
		5.57		5.57		5.90		5.14
	4.77	4.77	4.79	4.79	4.79	4.81		4.79
	3.59	3.59	3.60	3.59	3.59	3.59	3.62	3.58
		3.35		3.36		3.37	3.34	3.34
	3.02	3.03	3.02	3.03		3.06	3.03	3.03

is characteristic of minerals of the montmorillonite group. The lower trace also shows a new peak at approximately 8.4 angstroms, which is the second order reflection of the expanded basal spacing. Because of the high iron content of the rock, the montmorillonite mineral in the sample is probably nontronite (iron-rich montmorillonite).

The peak at approximately 7.2 angstroms is not affected by glycolation and indicates that there is probably some kaolinite present in the samples. Actual serpentine and chlorite are also possibilities with this spacing, but their presence is doubtful. The peak at approximately 3.03 angstroms indicates the presence of calcite impurity associated with the sample. The samples from the lower portion of the "serpentine" mass probably have some biotite in them as indicated by the reflection recorded at approximately 10 angstroms in samples 8, 9, 10, 11, and 12.

As seen by comparison in Table 3, the samples from Elgin, Hilbig and Yost gave very similar diffraction patterns to those from Lytton Springs, indicating a very similar composition. The sample from Hilbig gave an exceedingly large reflection at 3.05 angstroms, indicating a much larger calcite content than the other two. The sample from Yost also indicated the presence of minor amounts of biotite.

Thin Section Analysis and Results

Many mineral materials may be studied to advantage in thin sections with a polarizing microscope. The thin sections used in this work were prepared by Ruperto Laniz at Stanford University in California. The thin sections show that the mass is fairly constant throughout the vertical section, but some changes are present. The first few slides will be described in detail and changes will be noted as they occur in the rest.

The slides will be described in decreasing order or progressively up the hole. The first slide is Slide 12 which represents a sample at 1929 feet below the surface of the ground. From its appearance this sample was located below the main body of igneous rock. The sample is composed of a brown clay matrix with radial aggregates of authigenic crystals. The crystals are possibly some type of zeolite. Sample 11, which is 14 feet up the hole, is composed mostly of altered igneous rock fragments averaging one millimeter in diameter. Most of the fragments are made up of olivine crystals in a glassy matrix containing small laths of plagioclase. Both the olivine and plagioclase are now altered to green clay. The original rock contained small amounts of biotite and pyrite which still remain in the fragments. Formaninifera and other fossil fragments within larger limestone fragments are also present. The matrix of the rock is an extremely fine grained calcite clay mud.

The next sample up the hole is very similar to Slide 11, except that more biotite is present, some of which looks almost authigenic within the calcite matrix. The sample still shows some fossil fragments from one-half to two millimeters in diameter, but the matrix filling the void spaces of the rock is now a crystalline calcite in place of the calcite clay mud. This sample as well as most of the samples examined can be called lithic tuff.

Sample 9 contains larger fragments of altered igneous rock, which have the same appearance as the previous fragments. This sample probably had a high original porosity (greater than 20 percent), but most of the pores are now filled with calcite. It might be noted here that all the samples show some type of altered titanium mineral, possibly leucoxene. The igneous rock fragments can be described as originally an olivine rich porphyry, which probably had a glassy matrix containing small crystals of plagioclase or melilite. The fragments in the slides described are subangular, indicating that there might have been some reworking.

In Sample 8 a very different mineral is encountered. The sample is composed mainly, as before, of igneous rock fragments, but in this sample, instead of an all calcite filling, some of the voids are filled with pale green clay and with a clear mineral similar to a zeolite. Sample 7 also contains the same three mineral fillers, and the particle size of the igneous fragments has increased. The original rock in this sample could probably have been classified as lapilli tuff or volcanic agglomerate. Sample 6 is very similar to Sample 7. Slightly smaller fragments are found in Sample 5, but they are the same igneous fragments with altered olivine crystals. The original porosity of this sample was also large, but the pores are now filled with the three previously described minerals. Sample 4 is very similar to Sample 5.

Angular particles, loosely packed and poorly sorted, giving a rather high initial porosity, are found in Sample 3. Pale green clay has since grown around the crystals, leaving very little pore space. None of the zeolite (?) material is present in this or the next two samples. The fragments in Sample 2 are even coarser than in Sample 3. They are poorly sorted, with very high initial pore space, which has since been filled in with calcite. There is much less pale green clay present.

Sample 1 contains a matrix which is darker than the igneous rock fragments. This is just the reverse of the previously described slides. Sample 1 is from the top few feet of the igneous mass, and the matrix is a dark mud, which was probably a volcanic dust containing many small particles of iron rich minerals. In this case the dark mud completely filled any pores present. The mud was probably worked into the top layers of fragments, which seem almost completely devoid of calcite.

Conclusions

From an overall look at the thin sections it would appear that the rock at Lytton Springs is probably the result of an explosive volcanic magma that was blown out into the Austin sea. Many smaller particles were single olivine crystals surrounded by small droplets of the magma. This phenomenon can be recognized in each thin section. The crystal of olivine in the center of a fragment has small green laths in the glassy matrix oriented around the crystal parallel to the crystal faces, as they would be arranged by normal surface tension.

The particles that were blown out formed a cone-shaped mass. As the explosions occurred, some cratering also took place around the neck of the plug. The portion of the plug containing the larger sized particles would probably be classified as lapilli tuff and agglomerate composed of olivine porphyry, while the rock composed of smaller particles would be classed as lithic tuff.

At the end of its active period the volcanic mass was left saturated with water, surrounded with Austin chalk, and overlain with Taylor marl. Sometime before the calcite filled the pores and the mass altered to montmorillonite, oil must have accumulated from nearby source beds. After the accumulation of the petroleum or during accumulation, most of the water was adsorbed by the newly formed montmorillonite, and the deposition of calcite was completed, so that at the present time very little water is encountered in any of the wells. The mass as a whole probably contains numerous fractures and joints since it is only normal for all rocks to have a jointing tendency. The nature of the rock and its method of formation have led to a very heterogeneous mass in which the areal and vertical extent of porosity is highly unpredictable and discontinuous.

CHAPTER V

PRODUCTION HISTORY

Initial production of wells in the field ranged from 5 barrels per day to 4000 barrels per day, depending mostly on the porosity and permeability of the "serpentine" penetrated, rather than the position on the dome.[5] The initial potentials of a majority of wells in the field have been broken into four groups and contoured in Figure 19. Due to the nature of the serpentine, as discussed previously, wells with excellent initial potentials are often surrounded by wells which had very low initial potentials.

Flush production from the field lasted only a very few years with the first five years production (1925-1930) accounting for 68 percent of the oil produced to January, 1961. It has been suggested by Gulf Oil Corporation that solution gas drive was responsible for production of about 7.7 million barrels of oil or about 77 percent of the accumulated production to 1961.[2] It has also been suggested that gravity drainage, accentuated by the thick sections and high structural relief of the "serpentine," is the predominant producing mechanism at the present time.

Type and Source of Oil

The oil produced from the Lytton Springs field has a paraffin base and a gravity of 38.5° API at 60°F and 0 psig.

It contains between 6 and 7 percent paraffin. A P.V.T. and viscosity analysis of recombined surface samples of oil and gas obtained from Well 27, Lease 3 (Figure 18) showed that at the estimated original saturation pressure of 650 psig, the oil had a formation volume factor of 1.10 barrels of reservoir oil per barrel of stock tank oil, and a gas solubility of approximately 100 cubic feet per barrel of stock tank oil. At the present time, the average reservoir pressure is approximately 134 psig. There has been no appreciable change in reservoir pressure for the past six to eight years. At the presently existing pressure, the formation volume factor of the oil is approximately 1.06, the gas solubility is 45 cubic feet per barrel, and the viscosity is approximately 2.5 centipoises. Today as in the past, very little is known about the formation of petroleum. It is the opinion of several authors that the shales and marls of the Upper Cretaceous supplied the organic material from which the oil was formed.[5,6] By comparison it may be shown that the oil found in the "serpentine" is very similar to that found in the Austin chalk and Eagle Ford formations and differs drastically from that found in the Edwards formation. The oil from the "serpentine" is fairly light oil with a paraffin base, while that found in the Edwards is a heavier asphaltic base oil. The oil from the "serpentine" probably originated somewhere above the Edwards limestone and quite possibly from the basal Taylor marls. The Taylor marl surrounds the "serpentine" mass and has been known to yield oil upon distillation.[5]

Production Stimulation Tests

In December 1951, Gulf Oil Corporation began operations of a random pilot water flood on Lease 3 (Figure 18). The project consisted of one injection well wherein the injection water was produced and metered from the lower water bearing formation (Edwards limestone) and allowed to enter the producing reservoir, all in one hole utilizing the natural head existing in the water producing zone.[12] After six months' operation, five Gulf wells had been flooded by the injected water without substantial increases in oil production and were abandoned. In September, 1952, the project was discontinued, but during the 38-week injection period 210,517 barrels of salt water had been injected.

At the start of the operation, water was injected into Well 28 at rates varying from 300 to 400 barrels per day. The rate was gradually increased until it reached 900 barrels daily at the end of the first month. Very soon after injection was begun, adjacent wells became affected by showing very slight increases in oil production and then becoming completely flooded with water. Six months after initiation of the flood, five surrounding wells had been shut in due to 100 percent water production. By September, 1952, no additional wells were apparently affected and the project was discontinued. However, after cessation of the flood, five additional wells were temporarily abandoned due to 100 percent water production.

Performance curves for the project are included as Figure 7. Some of the more obvious conclusions to be gained from the results of the flood are that water can be injected into the "serpentine" by natural head from the Edwards limestone and that the "serpentine" will take water in considerable quantities. Apparently water will advance laterally through the formation at a fairly rapid rate, but will not displace an appreciable amount of oil, since essentially, no increase in oil production was noted. The water may be traveling through a fracture system and, due to the hydration characteristics of the serpentine, it may also be closing off all of the intergranular porosity that it contacts. The end results of the pilot flood lead Gulf to the conclusion that a lateral water flood was unsuitable for this field.[2]

After several years of inactivity in the field, Gulf again tried to stimulate production. An air injection project was begun in October, 1960, when Gulf began injecting air into an upstructure well on Lease 1 and withdrawing oil from a downstructure well. Well 11 was used as the injection well and 19 as the producing well. Air was injected into 339 feet of section at a rate of approximately 3.5 MMCF per month at 92 psi. The duration of the project was five months and Gulf believes that only one well was affected favorably by the project (see Figure 18), its production rate being increased slightly. Although the investigation was experimental, to

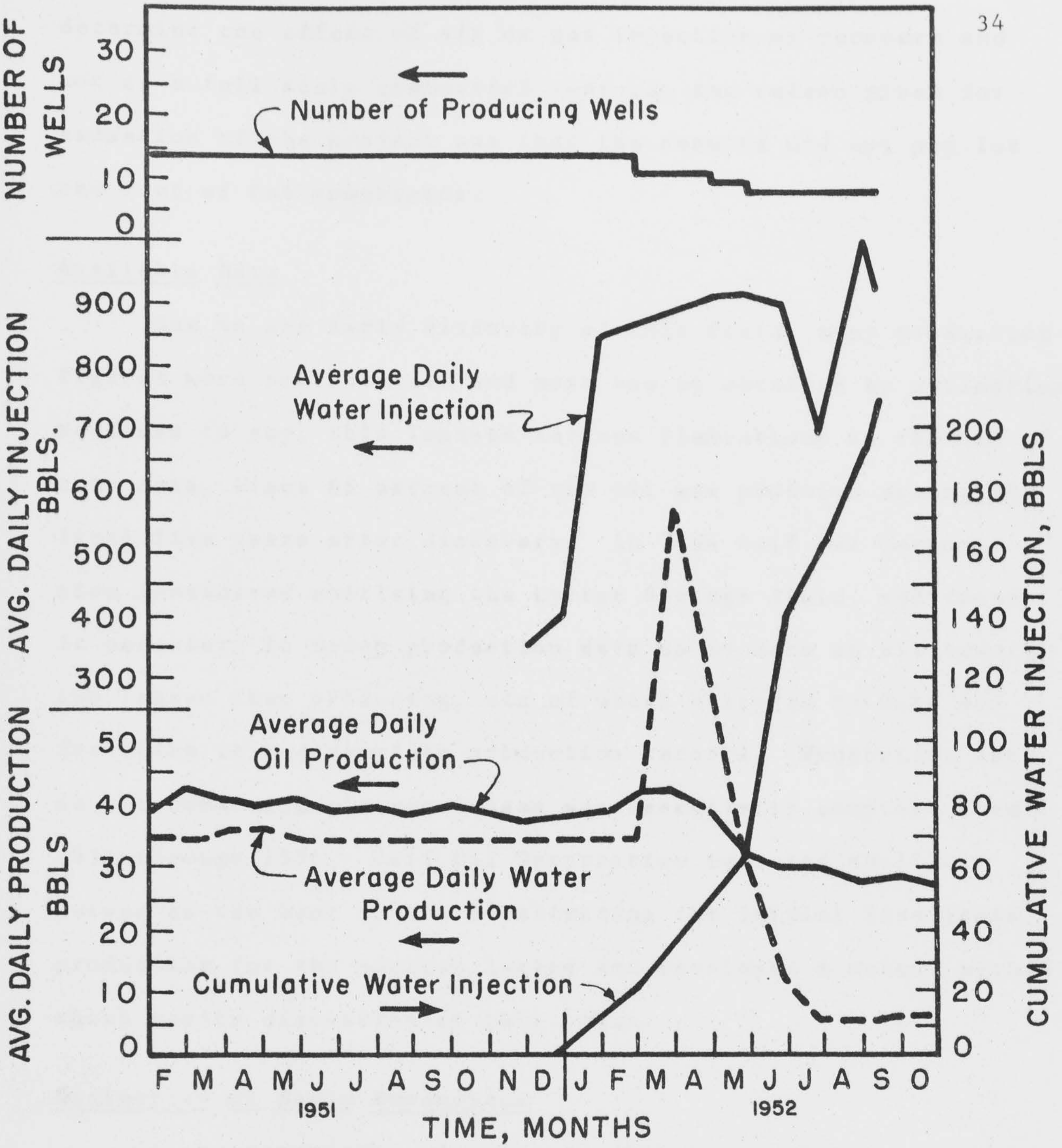


FIG. 7. PERFORMANCE CURVES OF PILOT WATERFLOOD PROJECT AT LYTTON SPRINGS FIELD

determine the effect of air or gas injection on recovery and not as a full scale commercial venture, the reason given for cessation of the project was that the results did not pay for the rent of the compressor.

Available Data

Due to the early discovery of this field, many production figures were not recorded and must now be obtained by estimation. Needless to say, this imposes serious limitations on the use of this data, since 68 percent of the oil was produced during the first five years after discovery. In 1954 Gulf Oil Corporation considered unitizing the Lytton Springs field, and found it necessary to bring production data up to date on all twenty-two leases then producing, six of which belonged to Gulf and for which it had complete production records. Production data on the remaining sixteen leases was essentially complete from 1931 through 1954. Gulf Oil Corporation selected decline curves as the best tool for estimating the initial five years production for the sixteen leases and developed a unique method which merits discussion at this point.

Estimation of Early Production

A characteristic of wells in this reservoir is a very high initial production with a very rapid decline immediately after the first 1-1/2 years, and a moderate decline thereafter. This phenomenon makes a straight line decline curve impossible to draw in the conventional manner, regardless of the type of graph paper used. After considerable experimenting, Gulf Oil Corporation managed to fit a straight line decline to their data in the following manner.[2]

1. Log-log paper was used for the plot of production rate versus time.
2. Production figures for the first two years, 1925 and 1926, were combined and the sum plotted as the initial year. Each succeeding year was shifted one year to the left on the graph. In other words, 1927 was plotted as the second year instead of the third, and so on.
3. A straight line was indicated in every case except for the initial year which invariably plotted above the line.
4. The straight line was extrapolated back to a point before the initial year where the initial year's production fell on the curve. For all practical purposes, this point was the same for all of Gulf's leases and has been labeled on Figure 8 as the "pseudo initial year."

The same principle was applied to the sixteen leases that were still producing, and the initial five years of production were estimated for each lease. Figure 8 is a graphic illustration of this method showing the total field plot and a plot of Lease 3.

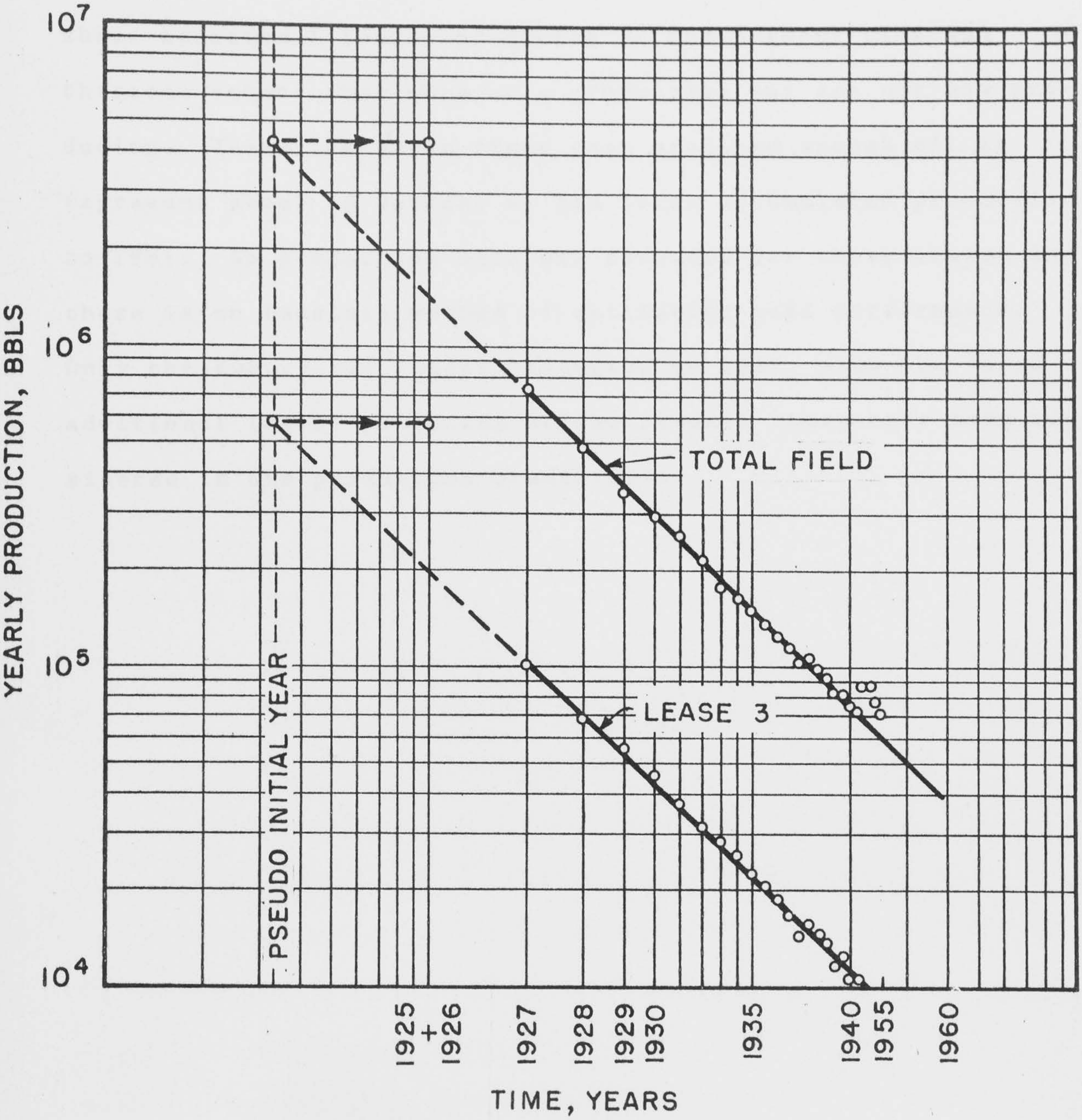


FIG. 8. ESTIMATION OF INITIAL FIVE YEARS PRODUCTION

Besides the twenty-two leases just discussed, there are three additional leases producing at the present time and thirteen others that were once productive but are not now producing. These leases in times past produced enough oil to represent about 18 percent of the total accumulated production to 1961. No production data was recorded for these leases and there is no feasible method of estimating past performance. Only the twenty-two leases producing in 1952, plus the three additional leases producing at the present time, have been considered in the production predictions.

CHAPTER VI

PRODUCTION PREDICTIONS

Due to the lack of adequate reservoir engineering data, and to the extreme heterogeneity of the producing formation, decline curve analysis is the only reliable tool for predicting production performance. Two types of decline curves were constructed: (1) production rate versus time and (2) production rate versus cumulative recovery. These curves are illustrated in Figures 9 through 13. It was found that during the past twenty years, the production decline has been of the exponential type as defined by Arps.[13] No shifting of data was necessary. The production rate versus time was plotted on semi-log paper and the production rate vs cumulative recovery was plotted on cartesian coordinate paper. Calculations were made using the rate-time curve, and cumulative recoveries were determined from the rate prevailing in 1961 down to zero rate. The values obtained from the calculations were then compared to recoveries indicated from extrapolation of the rate-cumulative curves and were in very close agreement in all cases. The equation used in the decline curve analysis is as follows:

$$Np = \frac{q_i - q}{D}$$

where: N_p = cumulative production during time interval that production is declining from q_i to q;

q_i = initial rate (rate in 1961);

q = rate at time T ($q = 0$);

D = -2.303 (slope) = cumulative decline fraction.

The solution and results of the decline curve analysis are shown in Table 7. Since the main purpose of this work is to determine the amount of oil capable of being produced, which remains in the formation, and not the amount that could be economically produced under present conditions, the time necessary for producing the indicated oil remaining was not calculated. For the same reasons, the decline curves drawn do not take into consideration the reduced rate for several of the leases due to the shutting in of several wells on the lease. The straight line decline rate-time and rate-cumulative curves were drawn through production points that represented the production potentials of the lease rather than the reduced capabilities obtained after numerous wells were shut in or abandoned.

Due to the great variation in thickness and large structural relief of the "serpentine" mass, it was necessary to calculate the volume of the productive formation underlying each lease, so that the production figures for the leases could be compared on a more equitable basis. For any future work in this field the value of oil per unit volume will be of significance, while the barrels of oil under a tract of land without

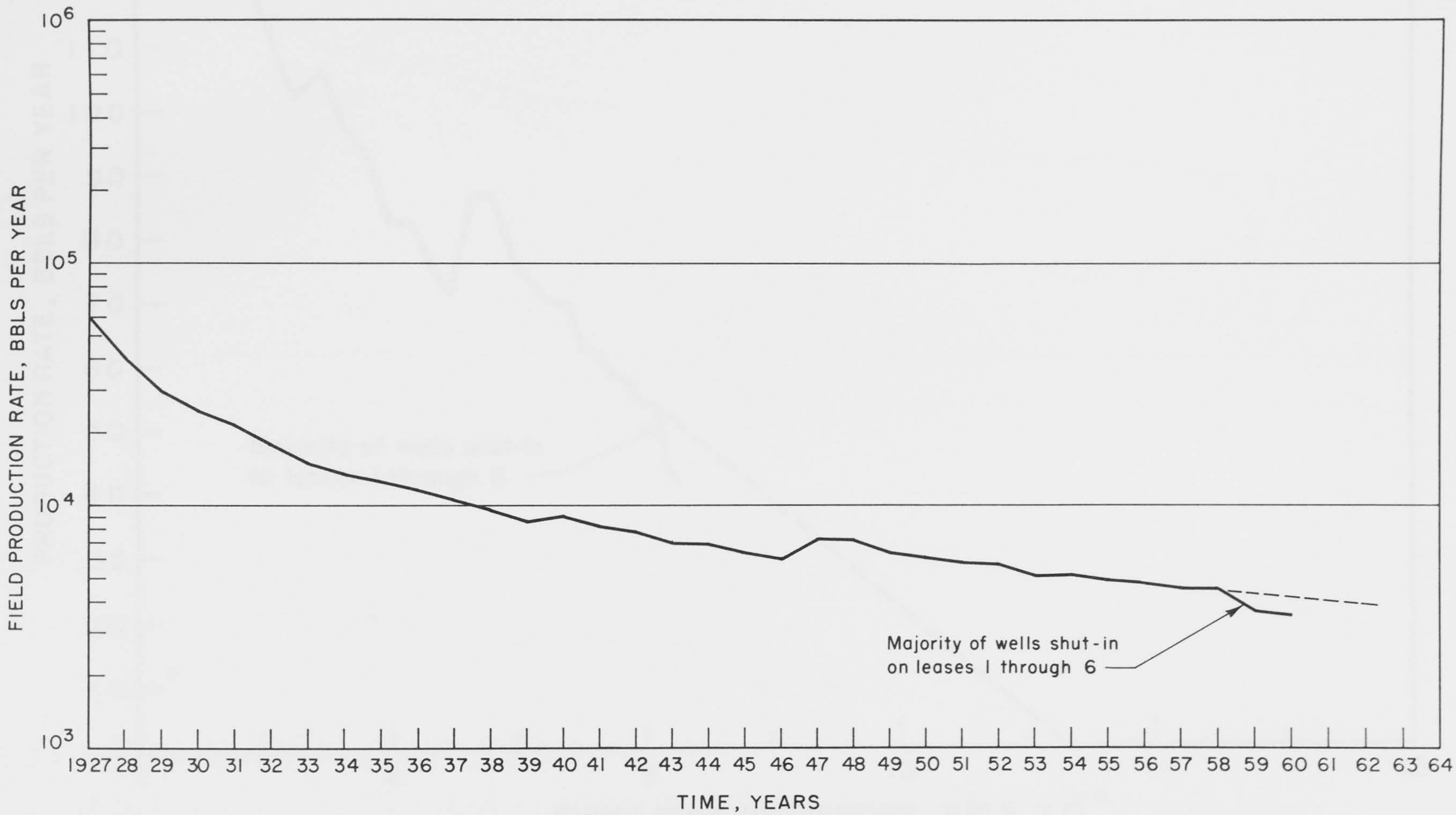


FIG. 9. FIELD PRODUCTION RATE VS. TIME

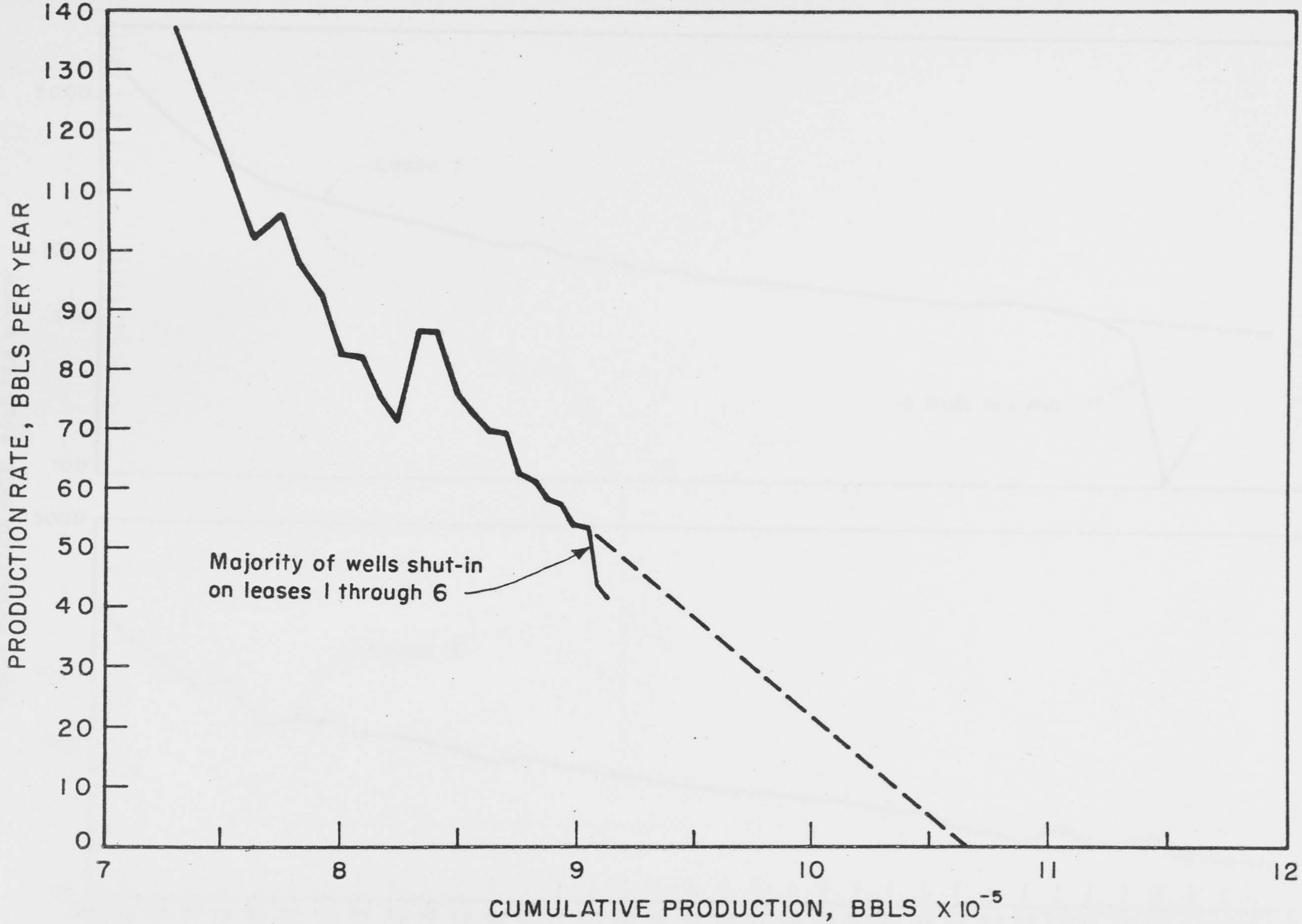


FIG. 10. FIELD PRODUCTION RATE VS. CUMULATIVE PRODUCTION

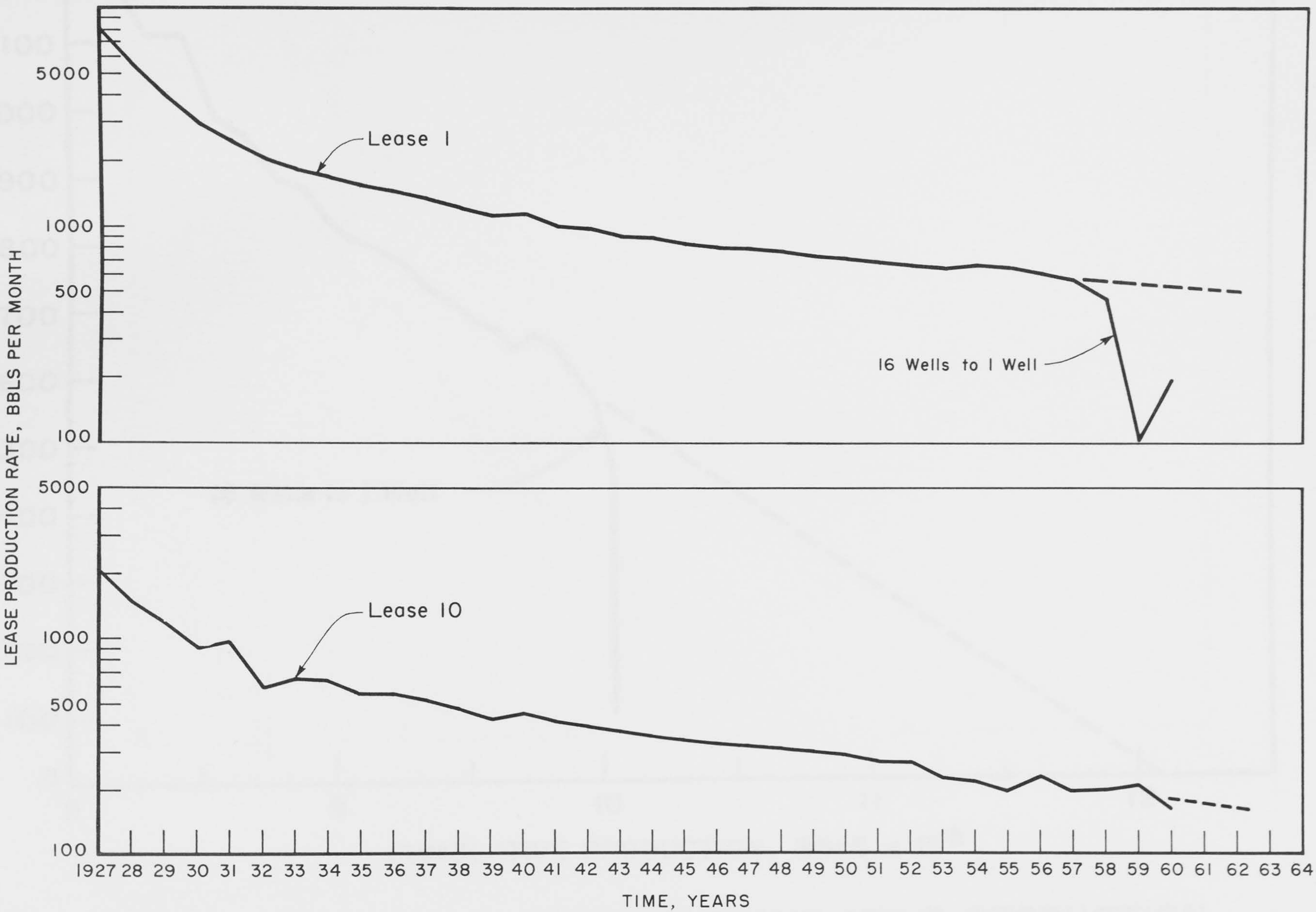


FIG. 11. PRODUCTION RATE VS. TIME, LEASES 1 AND 10

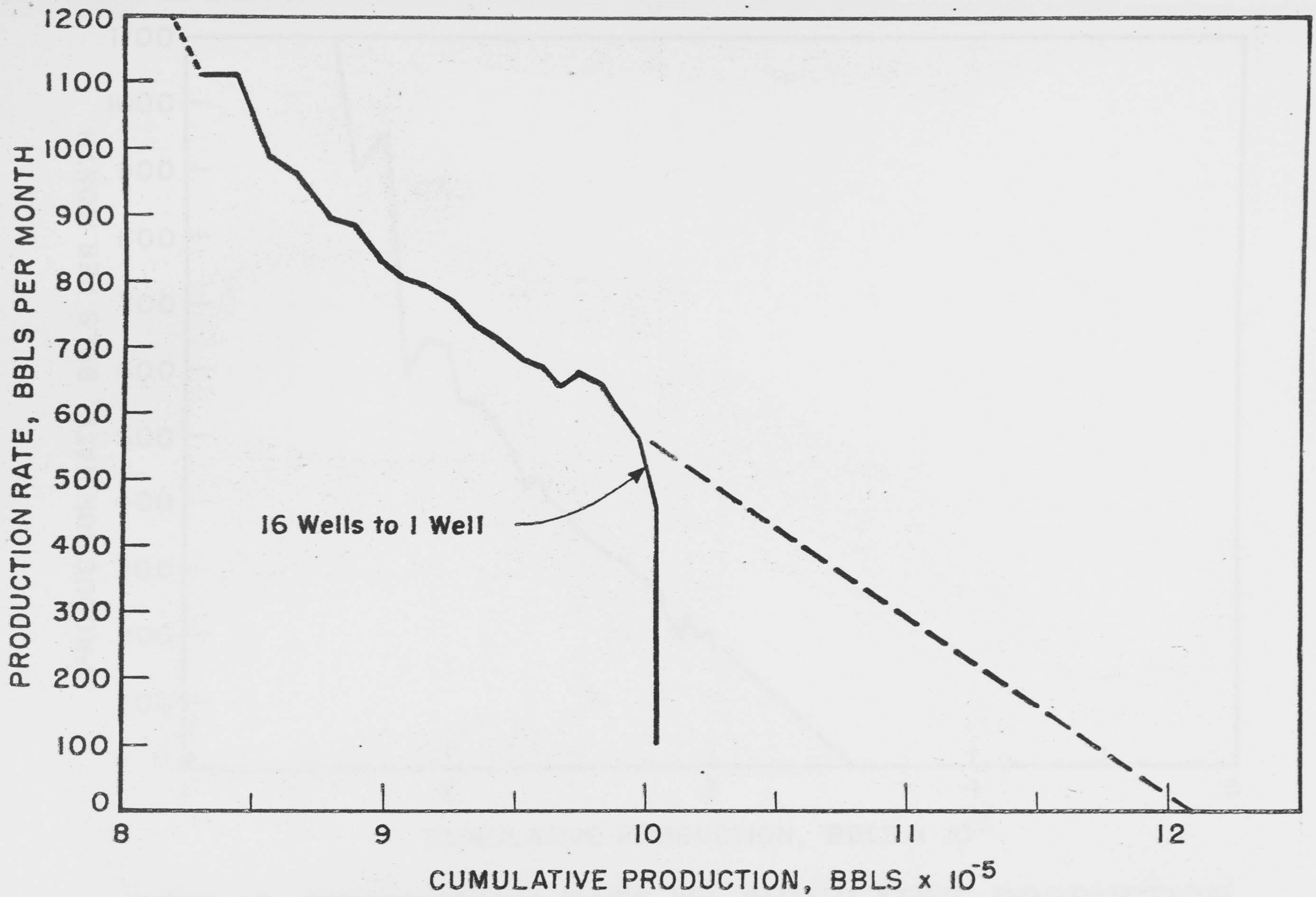


FIG. 12. PRODUCTION RATE VS. CUMULATIVE PRODUCTION, LEASE 1

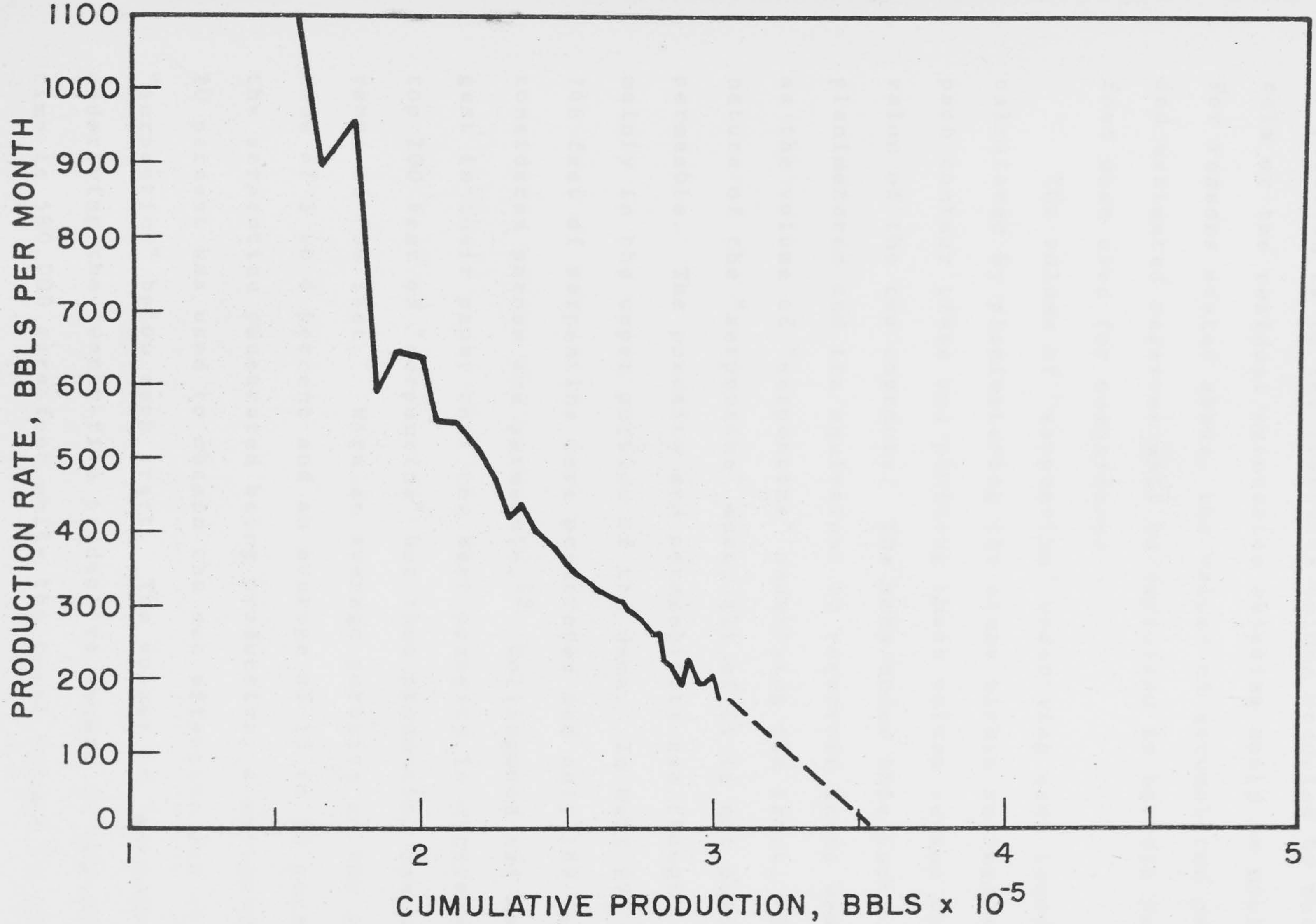


FIG. 13. PRODUCTION RATE VS. CUMULATIVE PRODUCTION, LEASE 10

stipulation as to the reservoir volume occupied by these barrels or the residual saturation existing could be misleading. For reasons stated above, the values of accumulated production and estimated reserves will be expressed in barrels per acre-foot when used for comparisons.

The volume of "serpentine" underlying each lease was calculated by planimetering the areas within successive isopach contour lines and plotting these values versus the average value of the two contours. The area under this curve was then planimetered and its equivalent in reservoir units was recorded as the volume of "serpentine" underlying the tract. Due to the nature of the "serpentine" mass, all of it is not porous and permeable. The porosity and permeability are thought to exist mainly in the upper portion of the dome. In Well 27, Lease 3, 746 feet of serpentine were penetrated and only 189 feet were considered porous and permeable.[12] Collingwood and Rettger suggest in their paper that the best porosity is obtained in the top 200 feet of "serpentine" but that production has a vertical range of 700 feet.[6] With an average porosity in the productive zone of 3 to 4 percent and an average of 15 to 25 percent of the serpentine penetrated being productive, a multiplier of 20 percent was used to obtain the net effective pay volume of "serpentine" below each tract. The volume of "serpentine" underlying the twenty-five productive leases at the present time is 580,000 acre-feet while the total volume is approximately

646,000 acre-feet. Applying the 20 percent factor we arrive at a net effective pay of 116,040 acre-feet below the twenty-five productive leases. Assuming an average porosity of 3 percent for the pay section of virgin "serpentine," a figure of 232 barrels per acre foot is arrived at for the average original oil saturation. This would have made the original oil-in-place equal to approximately 27,000,000 barrels. A little over 9,000,000 barrels of oil or approximately 34 per-cent of the original oil-in-place has been produced to date. As stated earlier, Gulf Oil Corporation suggested that 7,700,000 barrels of this oil were produced by solution gas drive and that that figure probably represented 30 percent of the original oil-in-place. The value of oil-in-place obtained in this manner is approximately 25,700,000 barrels as compared to 27,000,000 volumetrically.

The volume of "serpentine" underlying each of the twenty-five tracts now producing along with the total "serpentine" volume is shown in Table 8. From the values listed, the various production figures were placed on an acre-foot basis and are shown also in Table 8.

Method of Analysis

For purposes of illustration and analysis, the data for each parameter was broken into four groups of leases. These groups were picked at natural breaks in the data, with each group containing approximately 25 percent of the leases. Only those leases for which data was available were considered. The groups were numbered in numerical order, with Group I representing the best 25 percent of the leases with regard to any certain parameter. The range of each group is shown in Table 5. By use of cross hatching, the location of each group of leases is shown on Figures 20 through 23. Variation in one parameter only is shown on each map.

For determination of the effect of gravity drainage on the production to date and the remaining oil to be produced, some way of evaluating the gravitational movement of the oil down structure was needed. The centroid of the producing area was found by cutting out a replica of the area and suspending it successively in three different places with a pin and drawing plumb lines from each suspension point. The point of intersection of the three lines was the centroid of the surface area of the twenty-five producing leases. This point is shown in Figure 20 and corresponds quite well to the highest point on the structure. Distances from this point were then measured to the center of each lease and recorded in Table 9. The average distance from the centroid to each group of leases discussed above was then calculated and may be found in Table 5.

Results

The results of the analysis of the production data shows that the cumulative production per acre-foot to January, 1961, and also the total estimated production per acre foot to zero

TABLE 5

RANGE OF GROUPS* AND AVERAGE DISTANCE
OF GROUPS FROM THE CENTROID OF
PRODUCING AREA

	Group I	Group II	Group III	Group IV
Initial Potentials barrels/day	230	160-230	85-160	0-85
Distance**	2140'	3380'	2860'	3670'
Production per Acre-Foot 1925-1941	85	45-85	30-45	0-30
Distance**	3510'	2750'	2630'	3220'
Production per Acre-Foot 1941-1951	12.5	6.5-12.5	4-6.5	0-4
Distance**	2900'	2410'	2810'	3000'
Production per Acre-Foot 1951-1961	14	4.75-14	3.0-4.75	0-3
Distance**	3950'	2720'	2830'	2890'
Cumulative Production per Acre-Foot to 1961	85	50-85	20-50	0-20
Distance**	3140'	3230'	2800'	3190'
Estimated Future Production per Acre-Foot	30	15-30	6.25-15	0-6.25
Distance**	3850'	3150'	2625'	2520'
Estimated total Production per Acre-Foot	95	58-95	15-58	0-15

*Each group contains all leases falling within limits cited above for each particular variable.

**Average distance of leases in groups from centroid of production area in feet.

TABLE 9

AVERAGE INITIAL POTENTIALS PER LEASE AND DISTANCE OF LEASE FROM THE CENTROID OF THE PRODUCING AREA

Lease Number	Average Initial Potential B/D	Distance from Centroid, feet
1	113	2540'
2	144	2560
3	284	420
4	103	2200
5	133	3440
6	49	4300
7	170	3580
8	97	1720
9	90	4600
10	141	2960
11	180	3840
12	240	2820
13	405	1240
14	407	3840
15	332	2400
16	206	1600
17	175	2880
18	211	4350
19	71	3440
20	81	4000
21	---	3640
22	220	4040
23	---	3240
32	---	2920
36	---	5040

production rate, are related to the initial potentials. Figure 14 shows that the leases with the highest average initial potential have had the best recovery to 1961, and will probably have the best recovery to zero production rate, while the leases with the lowest initial potentials have had the lowest recovery to date and also probably will end up with the lowest overall recovery. The remaining oil to be produced does not seem to depend on the initial potentials; however, the leases containing the most reserves seem to be the Group II leases with respect to initial potentials. It can be seen on Figure 20 that the leases comprising Group II (initial potentials) are for the most part on the outer perimeter of the field.

The next figure (Figure 15) is a plot of the remaining oil to be produced per acre-foot to zero rate by groups versus the average distance of the groups from the centroid of the productive area. The observation gained from this figure is that the remaining oil to be produced per acre-foot to zero production rate seems to be connected to the distance of the lease from the centroid of the field area. In other words, the leases on the outer edge of the field seem to have the most potential oil per acre-foot while those close to the center seem to have the least. Figure 16 shows the movement of production with respect to time. It is a plot of the distances of the production interval groups from the centroid of the

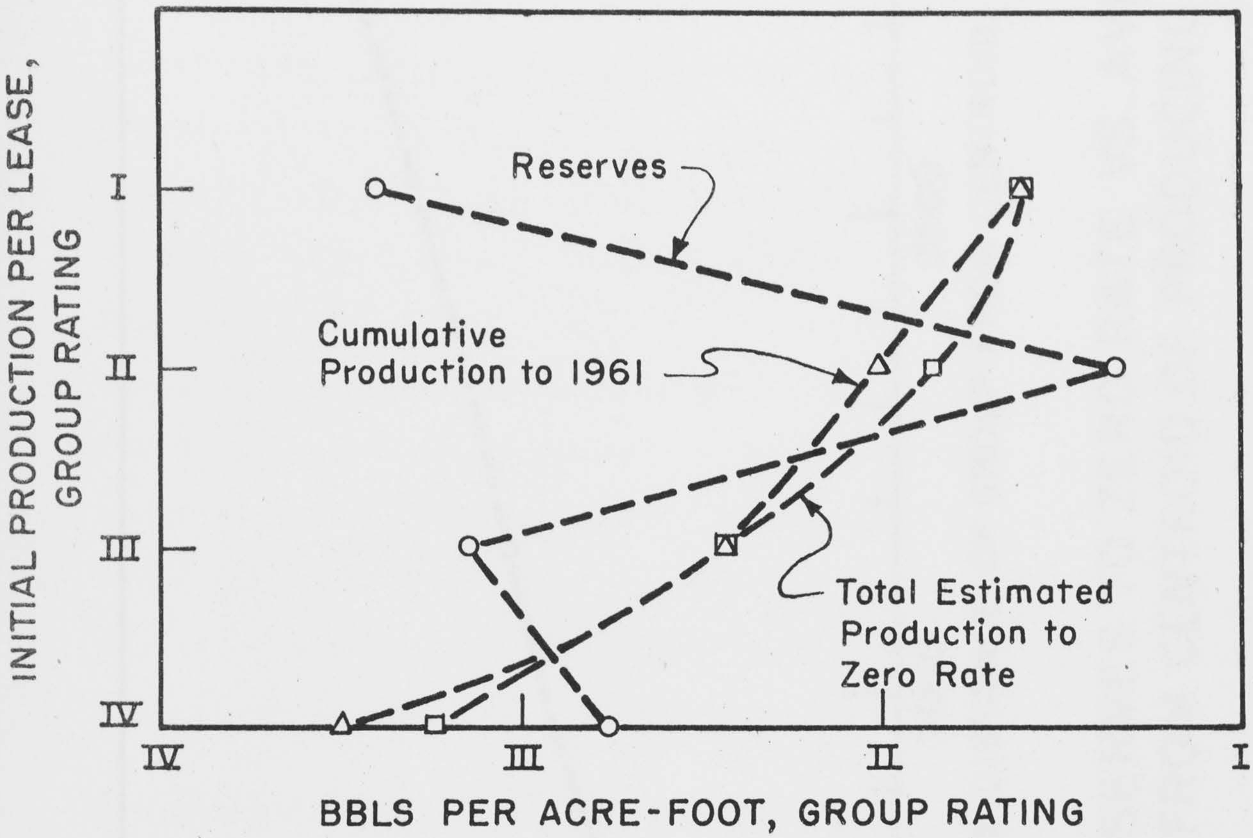


FIG. 14. INITIAL POTENTIALS VS. RESERVES, CUMULATIVE PRODUCTION TO 1961, AND TOTAL ESTIMATES PRODUCTION

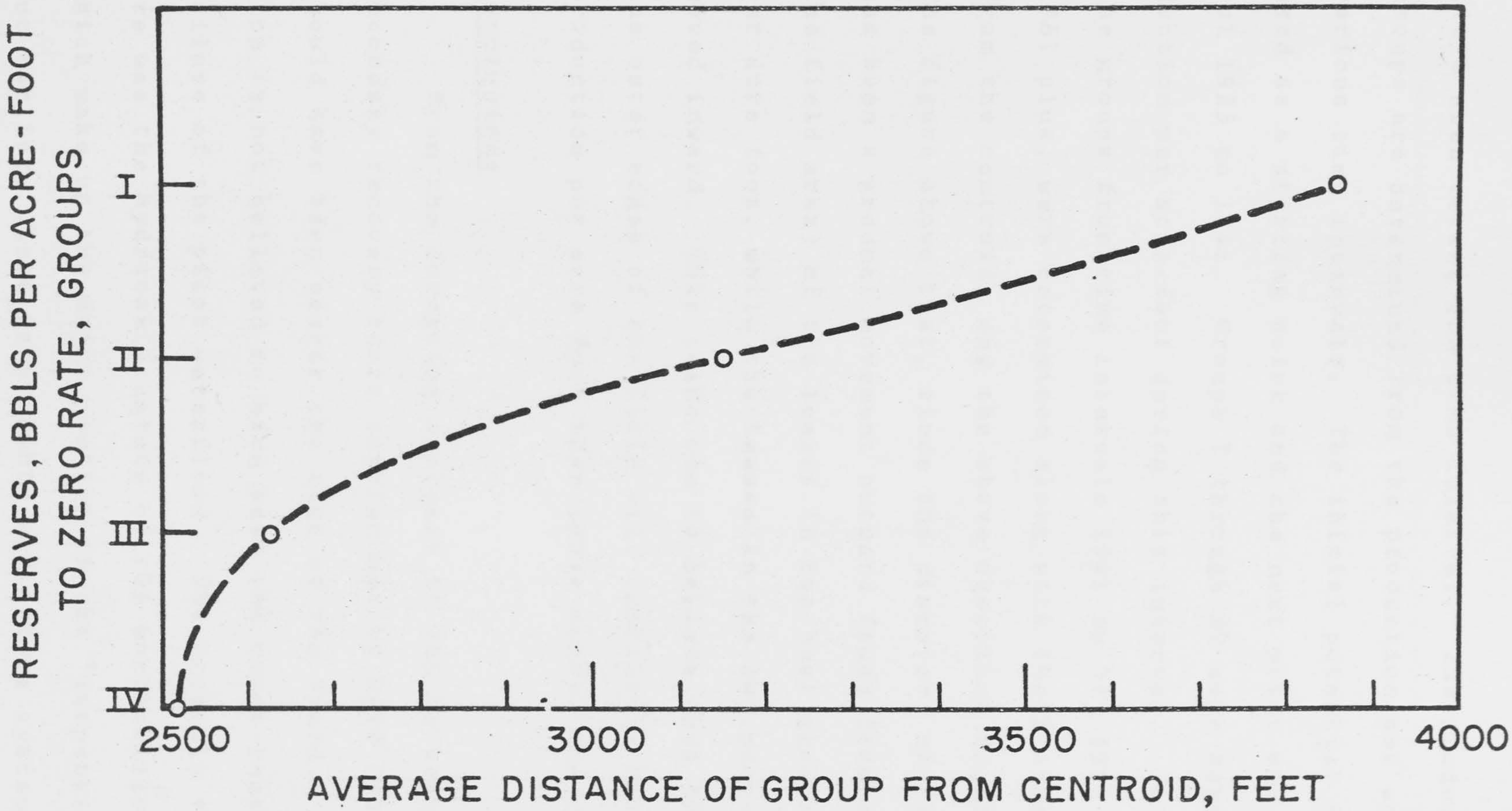


FIG. 15. RESERVES TO ZERO RATE VS. AVERAGE DISTANCE FROM CENTROID OF PRODUCING AREA

field area versus the time interval. The production interval groups are determined from the production per acre-foot during various time intervals. The initial potential groups were used as a starting point and the next point was the time interval 1925 to 1941. Groups I through IV were based on the production per acre-foot during this interval. In like manner, the groups from time intervals 1941 to 51, 1951 to 61, and 1961 plus, were determined along with their average distance from the centroid, and the above described figure plotted. The figure shows that, since the discovery of the field, there has been a gradual movement outward (away from the centroid of the field area) of the leases in two best groups of production per acre foot, while the leases in the two poorest groups have moved inward. This leads one to believe that the leases on the outer edges of the field will contribute more to future production per acre foot than those nearer the center.

Conclusions

From the foregoing analysis it can be seen that the pilot secondary recovery tests carried out by Gulf Oil Corporation should have been nearer the edge of the field. However, location is not believed to have been the major reason for the failure of the pilot waterflood. The probable reason for failure was the hydratable nature of the montmorillonite minerals which make up the major portion of the "serpentine." As pointed out earlier, there is probably a fracture system present through

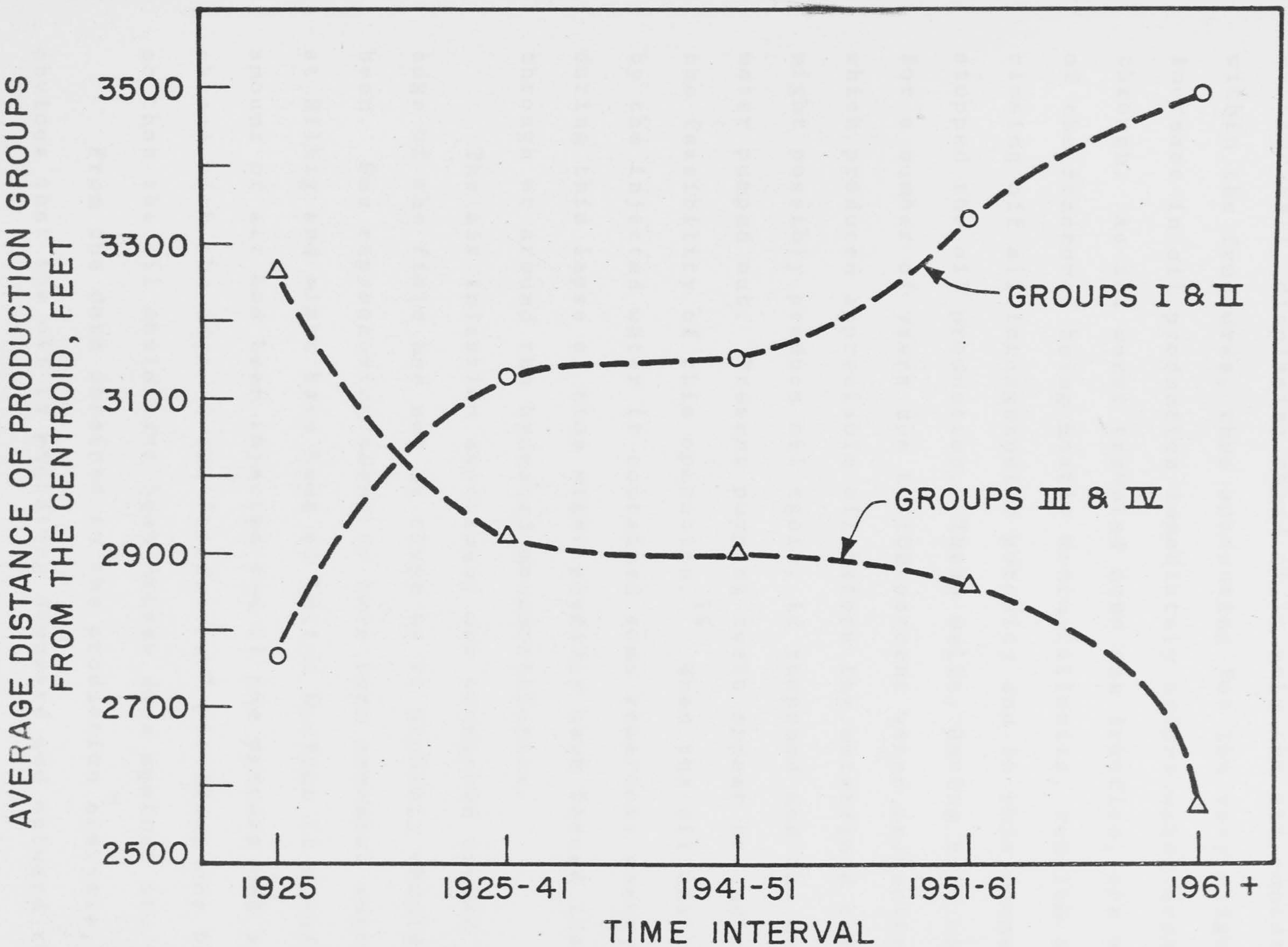


FIG. 16. AVERAGE DISTANCE FROM CENTROID OF PRODUCING AREA VS. TIME INTERVAL

which the water traveled rapidly from injection well to production well, displacing ahead of it only the oil contained within the fractures, thus accounting for the very slight increase in oil production immediately before water breakthrough. As the water traveled down the fraction, the walls of the fracture, being mostly montmorillonite, swelled slightly, closing off all intergranular porosity and in this manner stopped the oil production. These wells, having been abandoned for a number of years due to 100 percent water production, but which produced appreciable oil before the waterflood test, might possibly produce oil again, if reopened and the excess water pumped out. Present pumping tests appear to indicate the feasibility of this operation.[14] When the oil was trapped by the injected water it contained some reservoir energy, and during this lapse of time might possibly have forced its way through or around the hydrated montmorillonite.

The air injection experiment was conducted toward the edge of the field but not as close as it probably should have been. Gas repressuring seems to have been somewhat successful at Hilbig and might have been at Lytton Springs if a sufficient amount of air had been injected and if the pattern had been chosen with the edge of the "serpentine" providing one boundary so that the oil could have been driven down against it.

From the data obtained in the production analysis, it is obvious that the oil is migrating downward and outward through the "serpentine" rock resulting in resaturation of most of the edge leases. Since the porosity is found mostly in the upper 200 feet of "serpentine," very little, if any, beneficial results would be gained from deepening the productive wells near the center of the mass. Attention should be directed on the other hand to those leases near the outer perimeter of the plug that show relatively flat decline curves indicating relatively high residual saturations and sustained production through gravity drainage.

CHAPTER VII

SUMMARY AND RECOMMENDATIONS

The Lytton Springs oil field located in Caldwell County, Texas, was investigated to determine additional information about the nature and composition of the altered igneous rock from which oil is being produced, and also to determine the effect gravity drainage will have on the areal location of future production from this field. Lytton Springs has produced slightly over nine million barrels of oil to date, leaving approximately eighteen million barrels or 70 percent of the original oil still in place.

X-ray analysis of samples of the producing rock show it to be composed mainly of hydratable montmorillonite minerals. The thin sections show that the original rock resulted from an explosive volcano during the late Cretaceous. The original rock was probably an olivine porphyry, with distinct crystals of olivine in a fine-grained glassy matrix, which was blown out with explosive force, forming a cone of fragments around the neck of a volcano. The lower samples contain pieces of shell fragments, indicating that they have been slightly reworked. The igneous body can be classified as a tuff, varying between a lithic tuff and a lapilli tuff or agglomerate. When the particles were first in place, the "serpentine" mass was very porous, but subsequent deposition of calcite and other minerals has reduced the porosity until at the present time it averages only about three percent.

The presence of montmorillonite more than likely was the cause for failure of the water flood, while insufficient amounts of injected air, coupled with the heterogeneous nature of the "serpentine" probably spelled "failure" for the pilot air injection program. The possibility of recovering even a small percentage of the estimated eighteen million barrels of oil remaining in the formation should provide the incentive for additional work in this field. Any secondary recovery method tried must take into account the swelling nature of the "serpentine." With the small openings present and the large mass of rock, it would take only very slight swelling to seal off the pore spaces. The secondary recovery method most likely to be successful at the present time is probably a gas flood carried out on those leases indicated as being capable in the future of producing the most oil per acre-foot. Water-flooding as such is out of the question, but a possible line of future research would be to determine what inhibiters, if any, would prevent the swelling of the "serpentine" to a great enough extent to allow the water to enter the intergranular porosity and expell the oil. The fracture system might extend throughout the rock to such an extent that even successfully inhibited water could not be used.

In-situ combustion is probably unsuited, due to the low oil saturation per unit volume of rock and also to the fact that, with sufficient heating, the hydrated montmorillonite would lose water in the vicinity of the heat source and this water would be pushed ahead of the heat, causing the cooler montmorillonite to swell to a greater extent and possibly shut off all permeability to air and snuff out the source of the heat. Due to the large volume of rock to be swept, miscible flooding would probably be too expensive.

From the geologic standpoint it would be interesting to gain additional knowledge about the mineralogy of the rock and the process of alteration that has taken place.

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A P P E N D I X

TABLE 6

PRODUCING HISTORY OF TWENTY-FIVE LEASES
STILL PRODUCING AT LYTTON SPRINGS FIELD

Lease Number	1		2	
Year	Yearly Production BBLS	Cumulative Production BBLS	Yearly Production BBLS	Cumulative Production BBLS
1925 & 1926		409,351		130,230
1927	97,843	507,194	23,650	153,880
1928	66,372	573,566	16,450	170,330
1929	46,889	620,455	12,805	183,135
1930	35,128	655,583	11,290	194,425
1931	29,057	684,640	9,401	203,826
1932	24,234	708,874	8,198	212,024
1933	21,678	730,552	6,771	218,995
1934	20,055	750,607	6,067	224,862
1935	18,097	765,704	5,587	230,449
1936	17,062	785,766	4,946	235,995
1937	15,949	801,715	4,286	239,631
1938	14,616	816,331	4,162	243,843
1939	13,388	829,719	3,626	247,469
1940	13,512	843,231	4,071	251,540
1941	11,918	855,149	4,135	255,675
1942	11,577	866,726	3,737	259,412
1943	10,715	877,441	2,844	262,256
1944	10,626	888,067	3,186	265,442
1945	9,990	898,057	2,778	268,220
1946	9,670	907,727	2,324	270,544
1947	9,545	917,272	2,274	272,818
1948	9,252	926,524	2,877	275,695
1949	8,774	935,289	2,930	278,625
1950	8,591	943,889	2,602	281,227
1951	8,212	952,101	2,432	283,659
1952	8,041	960,142	2,418	286,077
1953	7,723	967,865	2,443	288,525
1954	7,964	975,829	2,392	290,917
1955	7,791	983,620	2,350	293,267
1956	7,277	990,897	2,162	295,429
1957	6,832	997,729	1,822	297,251
1958	5,596	1,003,325	1,472	298,723
1959	1,247	1,004,572	320	299,043
1960	2,379	1,006,951	332	299,375

TABLE 6—Continued.

Lease Number	3		4	
Year	Yearly Production BBLS	Cumulative Production BBLS	Yearly Production BBLS	Cumulative Production BBLS
1925 & 1926		572,169		277,477
1927	92,499	664,668	41,122	318,599
1928	68,064	732,732	26,094	344,693
1929	54,814	787,546	20,100	364,793
1930	45,441	832,987	17,740	382,533
1931	37,587	870,574	15,404	397,937
1932	31,125	901,699	12,535	410,472
1933	28,232	929,931	10,138	420,610
1934	25,753	955,684	8,855	429,465
1935	22,483	978,167	8,034	437,499
1936	20,810	998,977	6,572	444,071
1937	18,749	1,017,726	6,042	450,113
1938	16,554	1,034,280	5,484	455,598
1939	14,348	1,048,628	4,348	459,946
1940	15,596	1,064,224	4,834	464,780
1941	14,784	1,079,008	5,257	470,037
1942	13,934	1,092,932	4,882	474,919
1943	11,510	1,104,442	4,984	479,903
1944	12,347	1,116,789	5,033	484,936
1945	10,627	1,127,416	4,147	489,083
1946	10,716	1,138,132	3,469	492,553
1947	22,499	1,160,631	3,427	495,979
1948	22,438	1,183,069	3,984	499,963
1949	17,852	1,200,921	3,334	503,297
1950	16,216	1,217,137	3,221	506,518
1951	14,361	1,231,498	3,384	409,902
1952	11,817	1,243,315	2,955	512,857
1953	8,741	1,252,056	1,869	514,726
1954	8,655	1,260,711	1,474	516,200
1955	7,794	1,268,505	1,545	517,745
1956	6,901	1,275,406	1,439	519,184
1957	6,259	1,281,665	1,449	520,633
1958	5,892	1,287,557	1,651	522,284
1959	4,191	1,291,748	1,344	523,628
1960	3,891	1,295,639	1,148	523,952

TABLE 6—Continued.

Lease Number	5		6	
Year	Yearly Production BBLS	Cumulative Production BBLS	Yearly Production BBLS	Cumulative Production BBLS
1925 & 1926		177,461		17,645
1927	35,321	212,782	5,161	22,806
1928	22,126	234,908	4,100	26,906
1929	16,597	251,505	3,278	30,184
1930	13,809	265,314	2,798	32,982
1931	11,562	276,876	2,374	35,356
1932	10,111	286,987	2,143	37,499
1933	8,690	295,677	1,699	39,198
1934	7,835	303,512	1,489	40,687
1935	7,190	310,702	1,613	42,300
1936	6,607	317,309	1,722	44,022
1937	5,879	323,188	1,493	45,515
1938	5,734	328,922	1,391	46,906
1939	4,943	333,865	1,478	48,384
1940	4,979	338,844	1,382	49,766
1941	4,398	343,242	677	50,443
1942	4,556	347,798	387	50,830
1943	4,457	352,255	441	51,271
1944	4,262	356,517	370	51,641
1945	3,687	360,204	375	52,016
1946	3,704	363,908	324	52,340
1947	3,703	367,611	279	52,619
1948	3,393	371,004	310	52,929
1949	3,356	374,360	330	53,259
1950	3,254	377,614	311	53,570
1951	3,038	380,652	361	52,931
1952	2,896	383,548	772	54,703
1953	2,865	386,413	682	55,385
1954	2,883	389,296	639	56,024
1955	2,793	392,089	675	56,699
1956	2,582	394,671	604	57,303
1957	2,405	397,076	569	57,872
1958	2,482	399,558	483	58,355
1959	2,456	402,014	279	58,634
1960	2,119	404,133	204	58,838

TABLE 6 — Continued.

Lease Number	7		8	
Year	Yearly Production BBLS	Cumulative Production BBLS	Yearly Production BBLS	Cumulative Production BBLS
1925 & 1926				100,000*
1927			11,000*	111,000
1928			6,700*	117,700
1929	3,646*	3,646	4,700*	122,400
1930	4,200*	7,846	3,600*	126,000
1931	4,020*	11,866	2,935	128,935
1932	3,828*	15,694	2,411	131,346
1933	3,624*	19,318	1,975	133,321
1934	3,480*	22,789		
1935	3,288*	26,086		
1936	3,144*	29,230		
1937	3,000*	32,230		
1938	2,856*	35,086		
1939	2,724*	37,810		
1940	2,592*	40,402	Shut down	
1941	2,460*	42,862		
1942	2,340*	45,202		
1943				
1944				
1945				
1946				
1947	Shut down		3,109	136,430
1948			2,292	138,722
1949			1,959	140,681
1950			1,493	142,174
1951	1,504	46,706	1,041	143,215
1952	3,813	50,519	951	144,166
1953	4,983	55,502	987	144,953
1954	4,996	60,498	834	145,787
1955	5,051	65,549	673	146,460
1956	4,830	70,359	498	146,958
1957	4,262	74,641	508	147,466
1958	3,969	78,610	452	147,918
1959	3,488	82,098	379	148,297
1960	3,365	85,463	381	148,678

*Estimated Production

TABLE 6—Continued.

Lease Number	9		10	
Year	Yearly Production BBLS	Cumulative Production BBLS	Yearly Production BBLS	Cumulative Production BBLS
1925 & 1926		13,000*		98,000*
1927	5,120*	18,120	24,400*	122,400
1928	4,170*	22,290	17,800*	140,200
1929	3,600*	25,890	14,300*	154,500
1930	3,200*	29,090	10,767	165,267
1931	2,489	31,579	11,461	176,728
1932	2,683	34,262	7,155	183,883
1933	2,294	36,556	7,769	191,652
1934	2,776	39,332	7,644	199,296
1935	2,296	41,628	6,602	205,898
1936	2,233	43,861	6,593	212,491
1937	2,161	46,022	6,205	218,696
1938	2,020	48,042	5,669	224,365
1939	1,893	49,935	5,065	229,430
1940	1,834	51,769	5,278	234,708
1941	1,534	53,303	4,826	239,534
1942	1,191	54,494	4,575	244,109
1943	779	55,273	4,384	248,493
1944	709	55,982	4,192	252,685
1945	381	56,363	4,002	256,687
1946	451	56,814	3,853	260,540
1947	302	57,116	3,784	264,324
1948	442	57,558	3,680	268,004
1949	385	57,943	3,493	271,497
1950	456	58,399	3,405	274,902
1951	616	59,015	3,192	278,094
1952	528	59,543	3,193	281,287
1953	557	60,100	2,710	283,997
1954	595	60,695	2,607	286,604
1955	566	61,261	2,331	288,935
1956	592	61,853	2,752	291,687
1957	561	62,414	2,315	294,002
1958	603	63,017	2,353	296,355
1959	606	63,623	2,520	298,875
1960	1,774	65,397	1,834	300,709

*Estimated production

TABLE 6—Continued.

Lease Number	11		12	
Year	Yearly Production BBLS	Cumulative Production BBLS	Yearly Production BBLS	Cumulative Production BBLS
1925 & 1926		146,000*		172,000*
1927	27,700*	173,700	31,100*	203,100
1928	19,000*	192,700	21,200*	224,300
1929	14,600*	207,300	16,200*	240,500
1930	7,319	214,619	9,507	250,007
1931	7,939	222,558	11,165	261,172
1932	5,694	228,252	7,416	268,588
1933	5,200	233,452	6,901	275,489
1934	5,913	239,365	7,668	283,157
1935	5,902	245,267	6,409	289,566
1936	5,704	250,971	6,179	295,745
1937	5,501	256,472	5,896	301,641
1938	5,087	261,559	5,048	306,689
1939	4,495	266,054	4,478	311,167
1940	4,387	270,441	4,678	315,845
1941	4,171	274,612	4,486	320,331
1942	3,886	278,498	4,209	324,540
1943	3,596	282,094	3,942	328,482
1944	3,557	285,651	3,752	332,234
1945	3,340	288,991	3,578	335,812
1946	3,064	292,055	3,405	339,217
1947	3,008	295,063	3,215	342,432
1948	3,058	298,121	3,098	345,530
1949	2,961	301,082	2,672	348,202
1950	3,179	304,261	3,012	351,214
1951	2,931	307,192	2,713	353,927
1952	2,820	310,012	2,658	356,585
1953	2,777	312,789	2,412	358,997
1954	2,638	315,427	2,069	361,066
1955	2,531	317,958	2,216	363,282
1956	2,558	320,516	2,143	365,425
1957	2,304	322,820	1,986	367,411
1958	2,416	325,236	1,819	369,230
1959	2,565	327,801	2,059	371,289
1960	2,535	330,336	1,737	373,026

*Estimated production

TABLE 6—Continued.

Lease Number	13		14	
Year	Yearly Production BBLS	Cumulative Production BBLS	Yearly Production BBLS	Cumulative Production BBLS
1925 & 1926				215,000*
1927			40,000*	255,000
1928			27,300*	282,300
1929			20,900*	303,200
1930			12,185	315,385
1931			13,739	329,124
1932			11,381	340,505
1933			8,997	349,502
1934			9,184	358,686
1935			8,661	367,347
1936	518	518	8,095	375,442
1937	1,160	1,678	7,494	382,936
1938	1,020	2,698	6,827	389,763
1939	1,033	3,731	6,153	395,916
1940	1,115	4,846	6,310	402,226
1941	895	5,741	5,673	407,899
1942	679	6,420	5,430	413,329
1943	725	7,145	5,212	418,541
1944	781	7,926	4,913	423,454
1945	629	8,555	4,332	427,786
1946	864	9,419	4,230	432,016
1947	2,829	12,248	4,295	436,311
1948	4,552	16,800	3,672	439,983
1949	3,321	20,121	2,320	442,303
1950	2,257	22,378	2,892	445,195
1951	1,711	24,089	3,480	448,675
1952	1,598	25,687	3,495	452,170
1953	1,331	27,018	2,917	455,087
1954	1,309	28,327	3,121	458,208
1955	1,049	29,376	2,626	460,834
1956	859	30,235	2,777	463,611
1957	932	31,167	2,518	466,129
1958	864	32,031	2,686	468,815
1959	749	32,780	2,473	471,288
1960	712	33,492	2,440	473,728

*Estimated production

TABLE 6—Continued.

Lease Number	15		16	
Year	Yearly Production BBLS	Cumulative Production BBLS	Yearly Production BBLS	Cumulative Production BBLS
1925 & 1926		380,000*		22,000*
1927	66,800*	446,800	4,400*	26,400
1928	45,400*	492,200	3,050*	29,450
1929	34,200*	526,400	2,360*	31,810
1930	13,624	540,024	1,935	33,745
1931	23,299	563,323	1,880	35,625
1932	20,347	583,670	2,019	37,644
1933	14,797	598,467	1,141	38,785
1934	16,784	615,251	1,947	40,732
1935	14,296	629,547	2,031	42,763
1936	12,857	642,404	1,991	44,754
1937	12,197	654,601	2,200	46,954
1938	10,651	665,252	2,526	49,480
1939	9,963	675,215	2,483	51,963
1940	11,553	686,768	2,618	54,581
1941	10,317	697,085	2,610	57,191
1942	9,934	707,019	2,795	59,986
1943	9,061	716,080	3,031	63,017
1944	8,174	724,254	2,737	65,754
1945	7,856	732,110	3,060	68,814
1946	7,167	739,277	2,493	71,307
1947	6,417	745,694	2,474	73,781
1948	5,868	751,562	2,574	76,315
1949	5,750	757,312	2,528	78,883
1950	5,313	762,625	2,309	81,192
1951	4,858	767,483	2,286	83,478
1952	4,922	772,405	2,534	86,012
1953	4,333	776,738	2,239	88,251
1954	4,089	780,827	2,622	90,873
1955	3,801	784,628	2,579	93,452
1956	3,454	788,082	2,200	95,652
1957	3,758	791,840	2,220	97,872
1958	3,378	795,218	2,269	100,141
1959	2,384	797,602	2,100	102,241
1960	2,304	799,906	2,159	104,400

*Estimated production

TABLE 6—Continued.

Lease Number	17		18	
Year	Yearly Production BBLS	Cumulative Production BBLS	Yearly Production BBLS	Cumulative Production BBLS
1925 & 1926		73,800*		42,500*
1927	17,200*	91,000	16,800*	59,300*
1928	12,300*	103,300	13,700*	73,000
1929	9,600*	112,900	11,800*	84,800
1930	5,590	118,490	8,999	93,799
1931	5,915	124,405	5,526	99,325
1932	6,069	130,474	4,000	103,325
1933	2,555	133,029	4,723	108,048
1934	4,253	137,282	7,952	116,000
1935	4,652	141,934	7,109	123,109
1936	3,951	145,885	6,761	129,870
1937	4,150	150,035	6,234	136,104
1938	3,783	153,818	6,566	142,670
1939	3,831	157,649	6,407	149,077
1940	3,571	161,220	6,211	155,288
1941	3,373	164,593	6,250	161,538
1942	3,303	167,896	5,729	167,267
1943	2,713	170,609	5,390	172,657
1944	2,869	173,478	5,684	178,341
1945	2,854	176,332	5,378	183,719
1946	2,274	178,606	5,120	188,839
1947	2,306	180,912	5,040	193,879
1948	2,183	183,095	4,904	198,783
1949	2,376	185,471	4,630	203,413
1950	2,464	187,935	4,433	207,846
1951	2,135	190,070	4,169	212,015
1952	2,068	192,138	4,038	216,053
1953	1,959	194,097	3,964	220,017
1954	2,123	196,220	3,868	223,885
1955	1,984	198,204	3,835	227,720
1956	1,791	199,995	3,594	231,314
1957	1,708	201,703	3,675	234,989
1958	1,680	203,383	3,254	238,243
1959	1,846	205,229	3,341	241,584
1960	1,774	207,003	3,279	244,863

*Estimated production

TABLE 6—Continued.

Lease Number	19		20	
Year	Yearly Production BBLS	Cumulative Production BBLS	Yearly Production BBLS	Cumulative Production BBLS
1925 & 1926		21,000*		4,000*
1927	9,400*	30,400	1,970*	5,970
1928	7,800*	38,200	1,670*	7,640
1929	6,900*	45,100	1,500*	9,140
1930	5,608	50,708	1,170	10,310
1931	5,794	56,502	1,266	11,576
1932	4,000	60,502	1,200	12,776
1933	4,849	65,351	916	13,692
1934	6,311	71,662	1,174	14,866
1935	4,530	76,192	1,187	16,053
1936	4,286	80,478	1,030	17,083
1937	4,422	84,900	794	17,877
1938	4,144	89,044	859	18,736
1939	3,827	92,871	861	19,597
1940	3,786	96,657	788	20,385
1941	3,597	100,254	772	21,157
1942	2,858	103,112	811	21,968
1943	3,713	106,825	847	22,815
1944	3,743	110,568	748	25,563
1945	3,379	113,947	799	24,362
1946	3,350	117,297	933	25,295
1947	2,928	120,225	858	26,153
1948	3,147	123,372	872	27,025
1949	2,911	126,283	850	27,875
1950	2,852	129,135	845	28,720
1951	2,707	131,842	699	29,419
1952	2,797	134,639	644	30,063
1953	2,616	137,255	595	30,658
1954	2,787	140,042	642	31,300
1955	2,675	142,717	617	31,917
1956	2,492	145,209	635	32,552
1957	2,277	147,486	707	33,259
1958	2,293	149,779	615	33,874
1959	2,296	152,075	602	34,476
1960	2,230	154,305	580	35,056

*Estimated production.

TABLE 6--Continued.

Lease Number	21		22	
Year	Yearly Production BBLS	Cumulative Production BBLS	Yearly Production BBLS	Cumulative Production BBLS
1925 & 1926		51,500*		152,000*
1927	8,380*	59,880	29,300*	181,300
1928	5,600*	65,480	20,300*	201,600
1929	4,200*	69,680	15,600*	217,200
1930	4,496	74,176	12,700*	229,900
1931	2,857	77,033	3,224	233,124
1932	2,800	79,833	9,376	242,500
1933	1,409	81,242	6,855	249,355
1934	2,577	83,819	6,621	255,976
1935	2,074	85,893	6,816	262,792
1936	2,031	87,924	6,189	268,981
1937	1,732	89,656	5,667	274,648
1938	1,481	91,137	4,998	279,646
1939	1,311	92,448	5,277	284,923
1940	1,125	93,573	4,898	289,821
1941	1,040	94,613	4,071	293,892
1942	992	95,605	4,058	297,950
1943	726	96,331	3,894	301,844
1944	518	96,849	3,842	305,686
1945	926	97,775	3,529	309,215
1946	840	98,615	3,371	312,586
1947	592	99,207	3,277	315,863
1948	678	99,885	2,944	318,807
1949	615	100,500	2,542	321,349
1950	576	101,076	2,600	323,949
1951	555	101,631	3,221	327,170
1952	573	102,204	3,681	330,851
1953	538	102,742	3,206	334,057
1954	556	103,298	2,627	336,684
1955	491	103,789	2,446	339,130
1956	465	104,254	2,577	341,707
1957	490	104,744	2,358	344,065
1958	447	105,191	2,306	346,371
1959	484	105,675	2,173	348,544
1960	422	106,097	2,025	350,569

*Estimated production

TABLE 6—Continued.

Lease Number	23		32		36	
Year	Yearly Production BBLS	Cumulative Production BBLS	Yearly Production BBLS	Cumulative Production BBLS	Yearly Production BBLS	Cumulative Production BBLS
	No production data available prior to 1956.					
1956	2,205	2,205				
1957	2,138	4,343				
1958	1,027	5,370	3,121	3,121	632	632
1959	878	6,248	1,393	4,514	1,641	2,273
1960	863	7,111	618	5,132	645	2,918

TABLE 6—Continued.

TOTAL FIELD

Year	Yearly Field Total BBLS	Yearly Accounted For, BBLS	Cumulative Field Total BBLS
1925 & 1926	4,318,935	3,075,133	4,318,935
1927	726,270	589,166	5,045,205
1928	481,176	409,196	5,526,381
1929	356,800	318,589	5,883,181
1930	297,721	231,106	6,180,902
1931	259,595	208,894	6,440,497
1932	215,123	178,725	6,655,620
1933	179,857	151,213	6,835,477
1934	161,819	154,338	6,997,296
1935	150,323	138,857	7,147,619
1936	137,164	129,281	7,284,783
1937	125,174	121,211	7,409,957
1938	113,254	111,477	7,523,211
1939	102,461	101,932	7,625,672
1940	106,003	105,118	7,731,675
1941	97,719	97,244	7,829,394
1942	92,372	91,853	7,921,766
1943	82,964	82,964	8,004,730
1944	82,043,	82,043	8,086,773
1945	75,647	75,647	8,162,420
1946	71,622	71,622	8,234,042
1947	86,161	86,161	8,320,203
1948	86,218	86,218	8,406,421
1949	75,889	75,889	8,482,310
1950	72,281	72,281	8,554,591
1951	69,606	69,606	8,624,197
1952	69,204	69,204	8,693,401
1953	62,252	62,252	8,755,653
1954	61,490	61,490	8,817,143
1955	58,419	58,419	8,875,562
1956	57,387	57,387	8,932,949
1957	54,053	54,053	8,987,002
1958	53,760	53,760	9,040,762
1959	43,814	43,814	9,084,574
1960	41,750	41,750	9,126,324

TABLE 7

CALCULATION OF RESERVES TO ZERO RATE

Type of Equation:

$$Np = \frac{qi - q}{D}$$

$$D = 2.303 \; \frac{\log q_1 - \log q_2}{T_2 - T_1}$$

Lease Number	(1) q_1	(2) $Time_1$	(3) q_2	(4) $Time_2$	(5) log q_1	(6) log q_2	(7) (5)-(6)	(8) (4)-(2)	(9) (7)/(8)	(10) D = 0.192 x (9)	(11) NP (3)/(10)	Estimated Total Prod. to Zero Rate, Barrels
1	725	1,950	530	1,960	2.8603	2.7243	0.136	10	0.0136	0.00261	203,000	1,209,951
2	221	1,950	147	1,960	2.3444	2.1673	0.1771	10	0.01771	0.00340	43,250	342,625
3	1,001	1,950	405	1,960	3.0004	2.6075	0.3929	10	0.03929	0.00754	53,750	1,348,389
4	127	1,953	113	1,960	2.1038	2.0531	0.0507	7	0.00724	0.00139	81,400	605,352
5	270	1,950	190	1,960	2.4314	2.2787	0.1527	10	0.01527	0.00293	64,900	469,033
6	59	1,953	39	1,960	1.7709	1.5866	0.1843	7	0.02633	0.00506	7,520	66,358
7	375	1,954	282	1,960	2.5740	2.4502	0.1238	6	0.02063	0.00346	81,500	166,963
8	76	1,952	30	1,960	1.8780	1.4829	0.3951	8	0.04939	0.00948	3,210	151,888
9	88	1,949	47	1,960	1.9445	1.6703	0.2742	11	0.02493	0.00479	9,780	75,177
10	270	1,950	180	1,960	2.4314	2.2553	0.1761	10	0.01761	0.00338	53,300	354,009
11	230	1,952	204	1,960	2.3617	2.3096	0.0521	8	0.00651	0.00125	163,200	493,536
12	281	1,946	145	1,960	2.4487	2.1614	0.2873	14	0.02052	0.00394	36,800	409,826
13	129	1,952	58	1,960	2.1106	1.7634	0.3472	8	0.04340	0.00833	6,960	40,452
14	260	1,952	202	1,960	2.4150	2.3054	0.1096	8	0.01370	0.00263	76,800	550,528
15	385	1,952	218	1,960	2.5855	2.3385	0.2470	8	0.03088	0.00593	36,800	836.706
16	209	1,949	180	1,960	2.3202	2.2553	0.0649	11	0.00590	0.00113	158,900	263.300
17	181	1,951	149	1,960	2.2577	2.1732	0.0845	9	0.00939	0.00180	82,600	289,603
18	345	1,951	271	1,960	2.5378	2.4330	0.1048	9	0.01164	0.00223	121,500	366,363
19	235	1,951	188	1,960	2.3711	2.2742	0.0969	9	0.01077	0.00207	90,800	245,105
20	60	1,951	53	1,960	1.7782	1.7243	0.0539	9	0.00599	0.00115	46,100	81,146
21	46	1,951	37	1,960	1.6628	1.5682	0.0946	9	0.01051	0.00202	18,320	124,417
22	230	1,952	173	1,960	2.3617	2.2381	0.1236	8	0.01545	0.00297	58,250	408,819
23	85	1,958	71	1,960	1.9269	1.8513	0.0756	2	0.0378	0.00726	9,780	16,891
32	46	1,959	42	1,960	1.6580	1.6233	0.0347	1	0.3047	0.00666	6,300	11,432
36	48	1,959	44	1,960	1.6812	1.6435	0.0377	1	0.0377	0.00724	6,090	9,008
Total											1,520,810	10,647,134
Field	5750	1,950	4,150	1,960	3.7600	3.6180	0.1420	10	0.0142	0.00273	1,520,000	10,646,324

TABLE 8

VOLUME OF "SERPENTINE" UNDERLYING EACH LEASE AND
PRODUCTION DATA EXPRESSED ON AN ACRE-FOOT BASIS

Jse Lease Nbe Number	Total Ac-Ft. of "Serpentine"	Net Effective Acre-Feet	Reserves Bbls./Ac-Ft. to Zero Rate	Cum. Prod., Bbls./Ac-Ft. to 1961	Est. Total Prod., Bbls./ Ac-Ft. to Zero Rate	Prod., Bbls./ Ac-Ft., 1925 to 1941	Prod. Bbls./ Ac-Ft., 1941 to 1951	Prod., Bbls./ Ac-Ft., 1951 to 1961
1	84,000	16,800	12.1	59.9	72.0	50.2	5.90	3.8
2	31,200	6,240	6.93	47.98	54.9	40.3	4.8	2.88
3	68,600	13,720	3.92	94.08	98.0	77.5	11.1	5.48
4	57,800	11,560	7.03	45.43	52.45	40.1	3.8	1.53
5	14,600	2,920	22.25	138.50	160.75	116.0	13.1	9.40
6	17,400	3,480	2.16	16.89	19.05	14.3	1.1	1.49
7	8,000	1,600	51.00	53.25	104.25	25.2	3.0	25.05
8	19,400	3,880	0.83	38.28	39.10	34.4	2.3	1.58
9	11,400	2,280	4.29	28.71	33.0	22.7	2.90	3.11
10	28,600	5,720	9.31	52.64	61.95	41.0	7.10	4.54
11	6,400	1,280	127.75	257.75	385.0	214.0	24.0	19.75
12	20,600	4,120	8.93	90.42	99.35	76.6	8.8	5.02
13	16,800	3,360	2.08	9.93	12.0	1.4	5.21	3.28
14	14,400	2,880	26.65	164.35	191.00	139.5	15.5	9.35
15	37,600	7,520	4.89	106.16	111.05	91.5	9.70	4.96
16	37,000	7,400	21.45	14.10	35.55	7.4	3.57	3.13
17	22,800	4,560	18.10	45.30	63.40	35.2	6.0	4.1
18	10,400	2,080	58.10	117.90	176.00	74.7	25.1	18.1
19	13,600	2,720	33.40	56.60	90.0	35.6	11.9	9.1
20	10,200	2,040	22.60	17.30	39.90	9.9	4.12	3.22
21	7,400	1,480	12.40	71.60	84.00	63.2	5.5	2.9
22	7,800	1,560	36.70	225.30	262.00	185.0	22.5	17.80
23	15,200	3,040	3.22	2.33	5.55	-	-	-
32	17,700	3,540	1.78	1.45	3.23	-	-	-
36	1,300	260	23.40	11.30	34.70	-	-	-
	580,200	116,040						
Total Field	646,000							

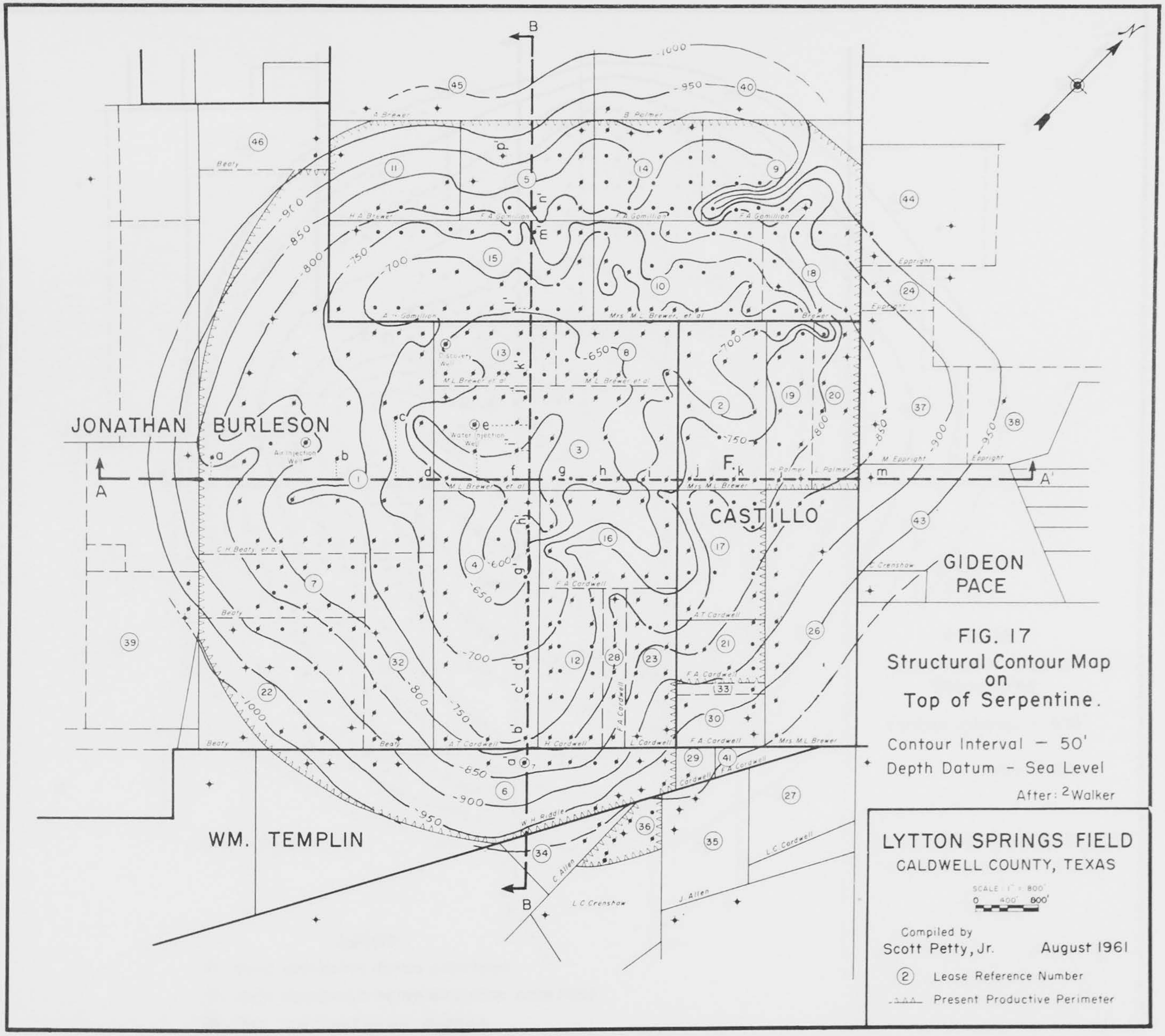


FIG. 17
Structural Contour Map on Top of Serpentine.

Contour Interval — 50'
Depth Datum - Sea Level
After: [2] Walker

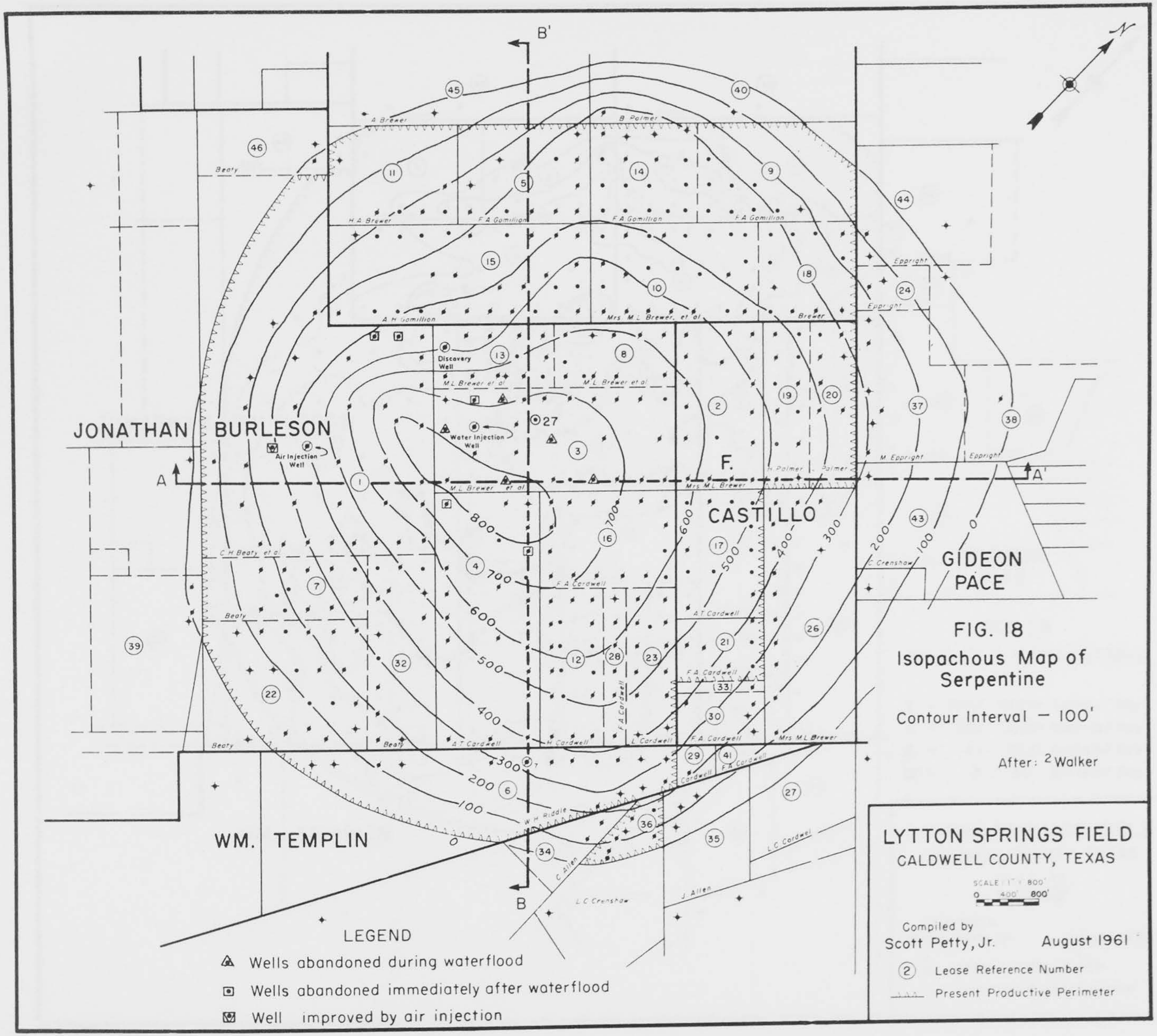


FIG. 18
Isopachous Map of Serpentine

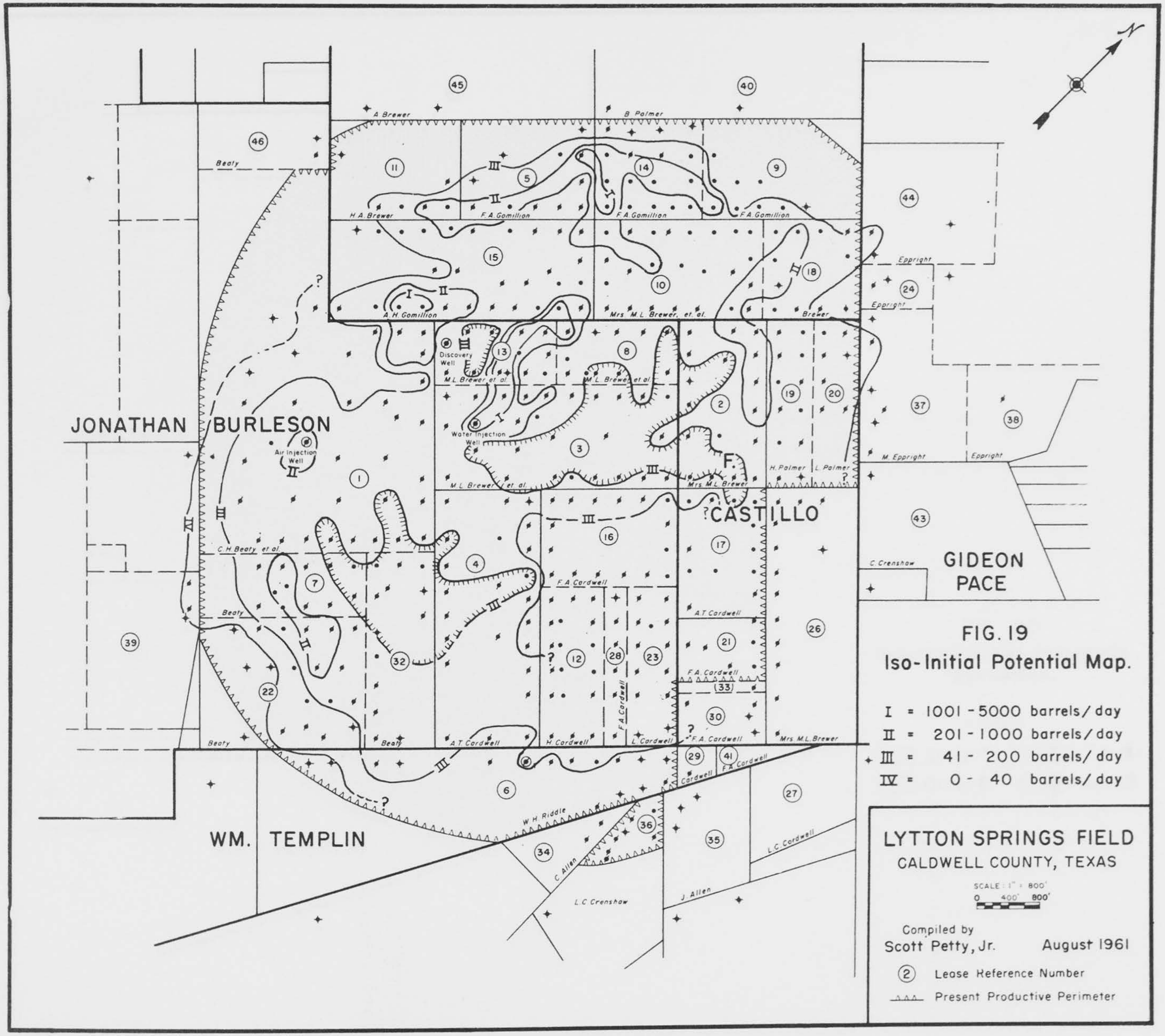


FIG. 19
Iso-Initial Potential Map.

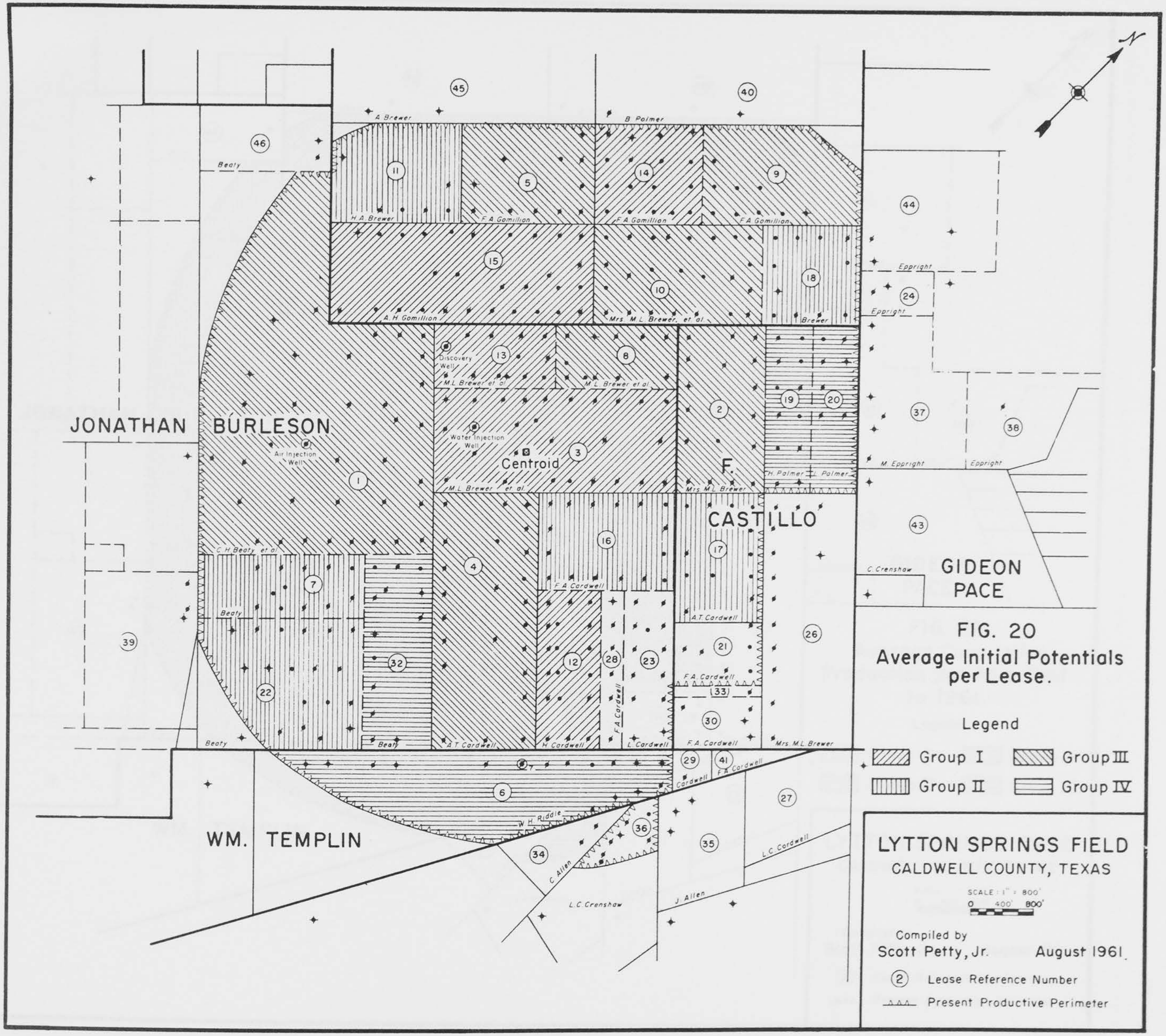
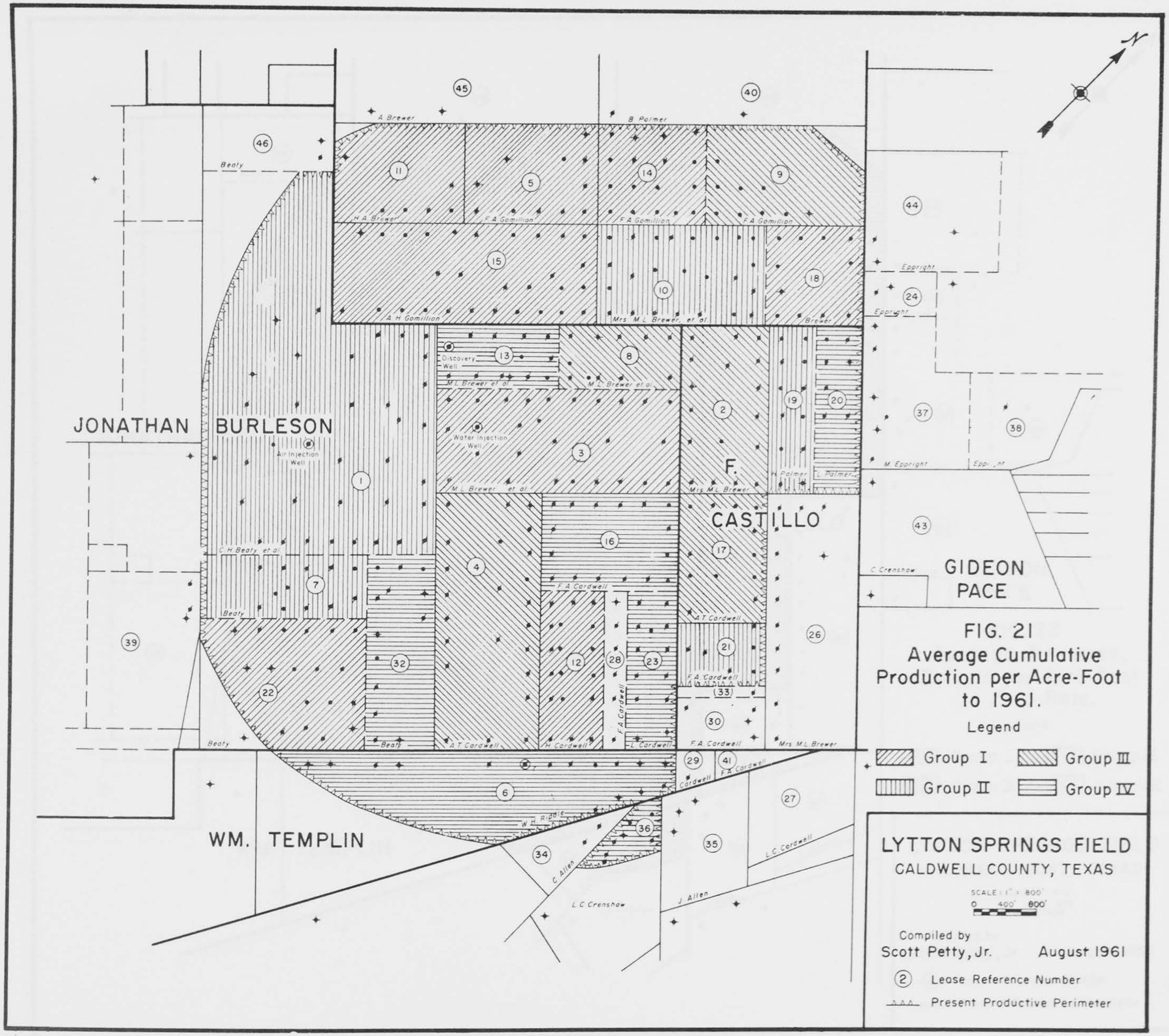


FIG. 20
Average Initial Potentials per Lease.



JONATHAN BURLESON
F. CASTILLO
GIDEON PACE
WM. TEMPLIN
Discovery Well
Water Injection Well
Air Injection Well
FIG. 21
Average Cumulative Production per Acre-Foot to 1961.
Legend
Group I
Group II
Group III
Group IV
LYTTON SPRINGS FIELD
CALDWELL COUNTY, TEXAS
Compiled by
Scott Petty, Jr.
August 1961
Lease Reference Number
Present Productive Perimeter

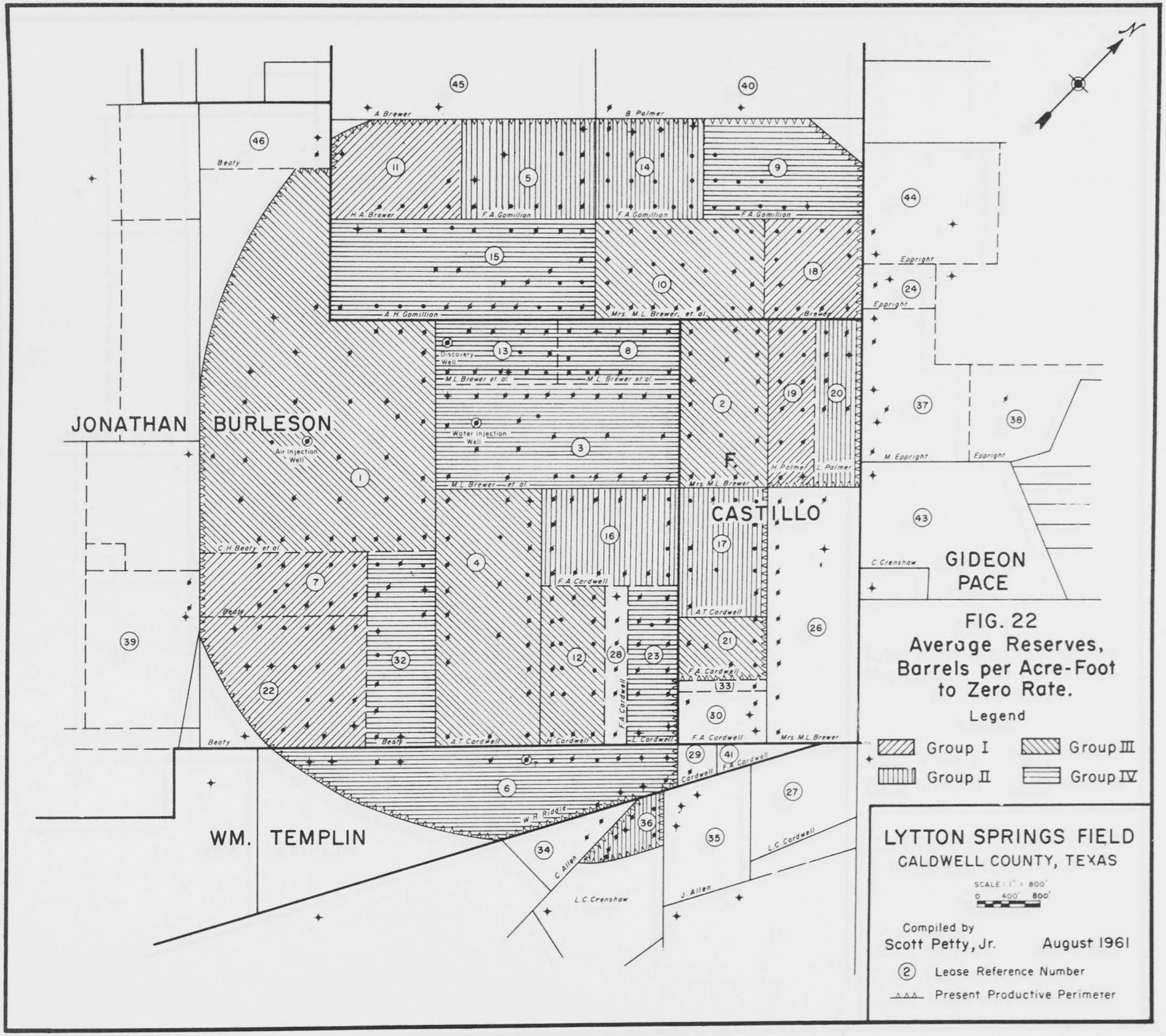


FIG. 22
Average Reserves, Barrels per Acre-Foot to Zero Rate.

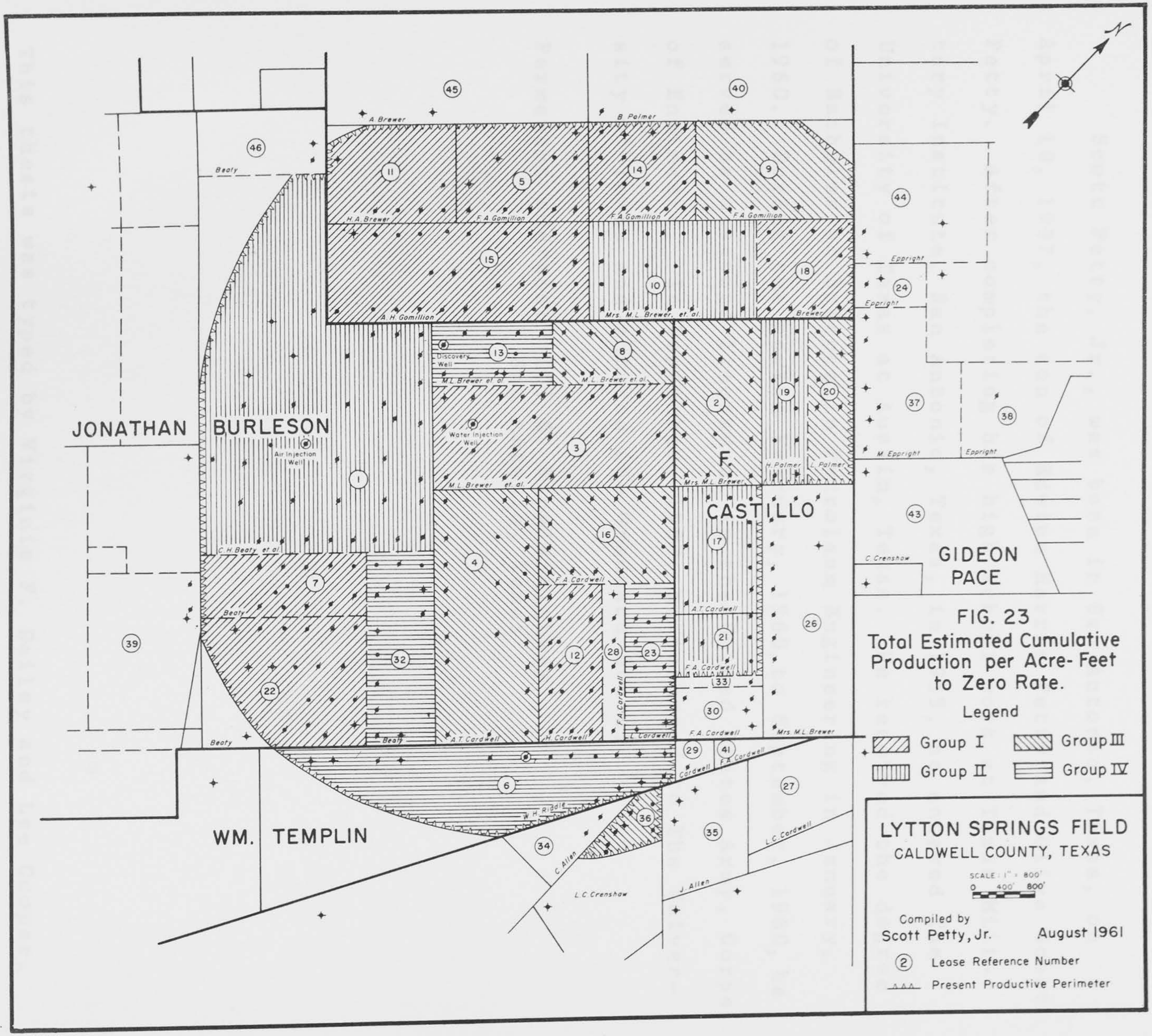


FIG. 23
Total Estimated Cumulative Production per Acre-Feet to Zero Rate.

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